

# Doctor's Insights : Investigating Closed Head Brain Injuries - an Update

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# Outline



- Anatomy and Function pertinent to Traumatic Brain Injury (TBI)
- Types of Traumatic Brain Injuries
- Emerging Diagnostic Tools: Biomarkers and Advanced imaging tools
- Controversies around Postconcussive Syndrome/PTSD
- What happens inside a concussed brain? Mechanical and Metabolic Factors
- Chronic conditions after TBI: Sleep disturbances, Headaches, Dizziness, Fatigue, Cognitive issues, Psychological/behavioral changes, visual/balance...
- Therapies for brain trauma recovery





# Cerebral Cortical Functions

## Motor Area

- control of voluntary muscles

## Sensory Area

- skin sensations (temperature, pressure, pain)

## Frontal Lobe

- movement
- problem solving
- concentrating, thinking
- behaviour, personality, mood

## Broca's Area

- speech control

## Temporal Lobe

- hearing
- language
- memory

## Brain Stem

- consciousness
- breathing

## Parietal Lobe

- sensations
- language
- perception
- body awareness
- attention

## Occipital Lobe

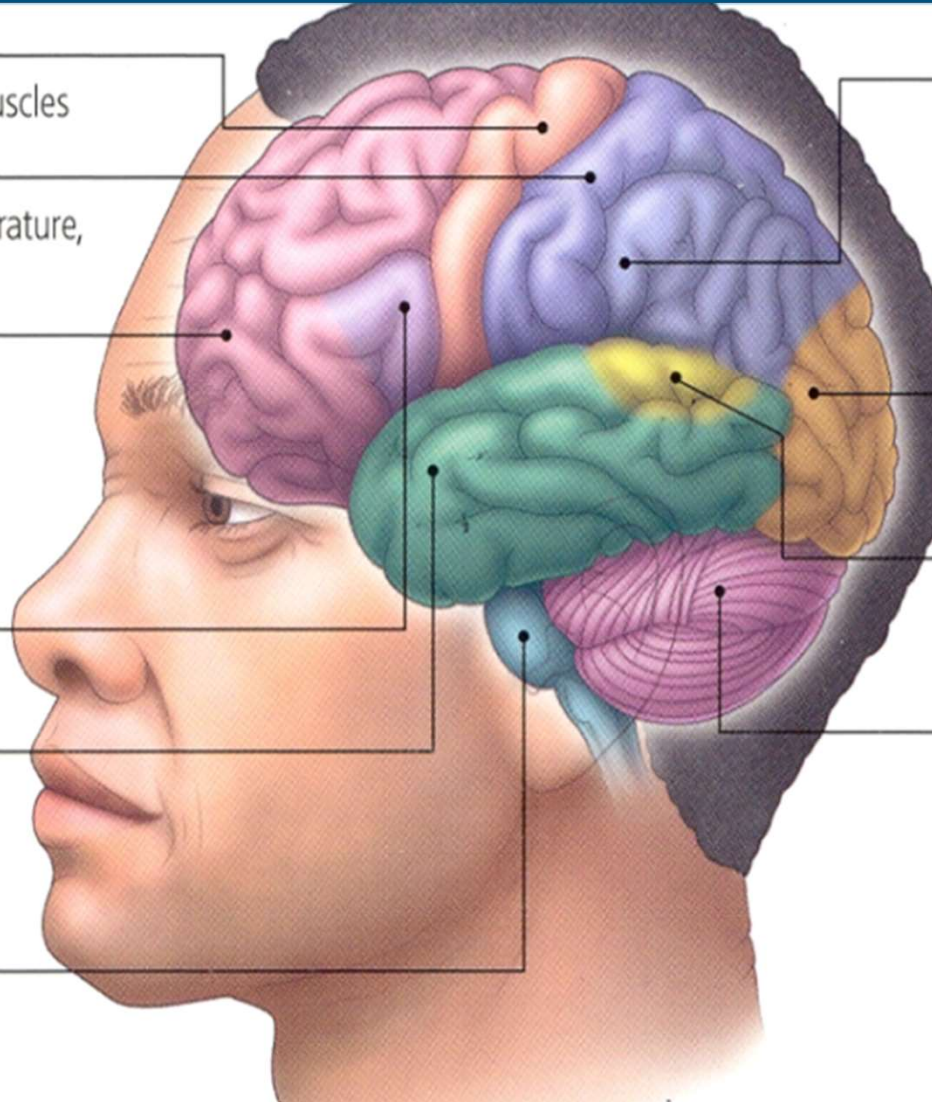
- vision
- perception

## Wernicke's Area

- language comprehension

## Cerebellum

- posture
- balance
- coordination of movement





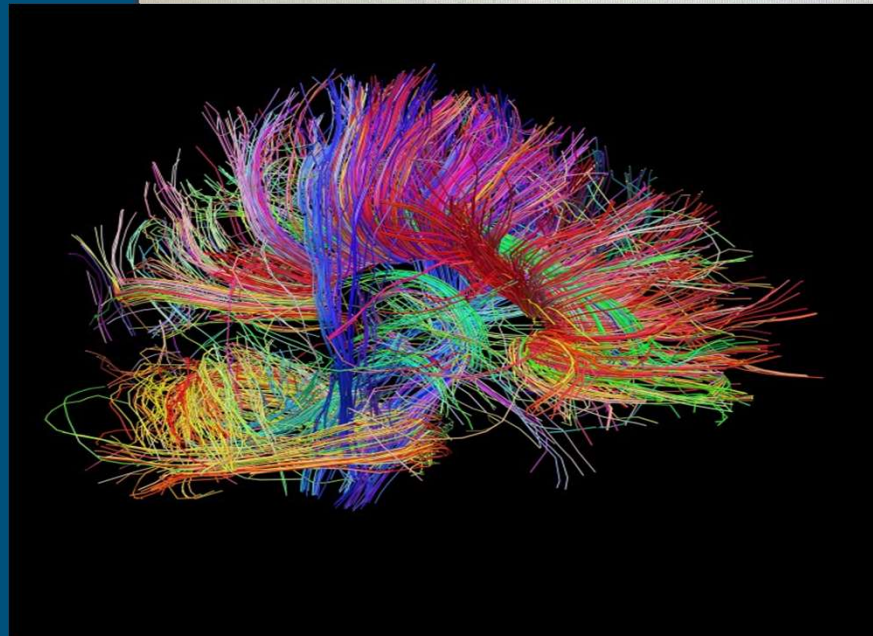
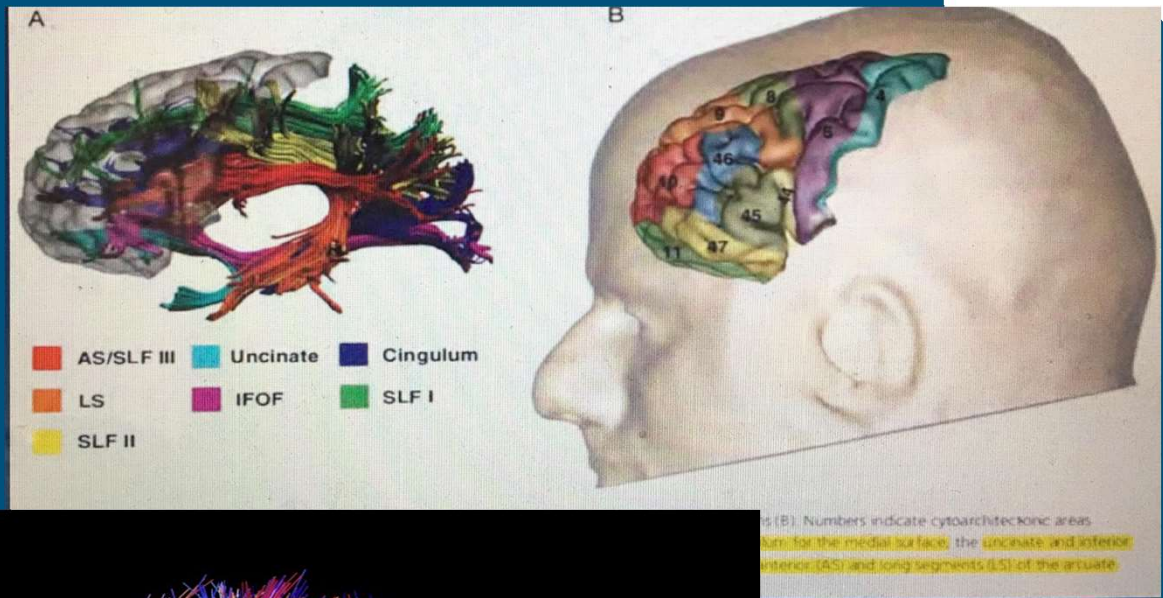
# The Brain functions as a Whole



Unlike other body parts, one cannot separate the portions of the brain that sustained injuries in terms of function

Functional “Connectome” - network patterns of various functions

e.g. **Default Mode Network**  
Limbic Network

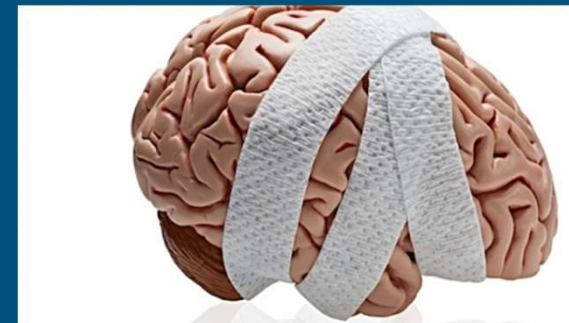






# Types of Brain Injuries

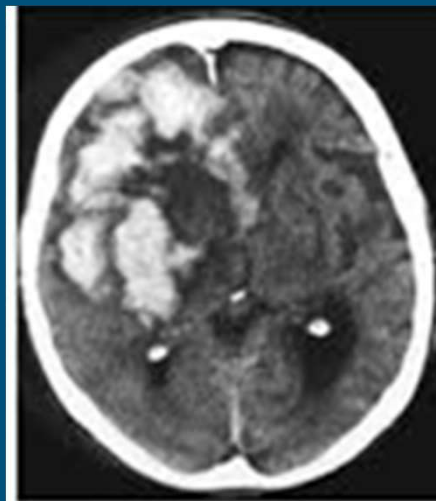
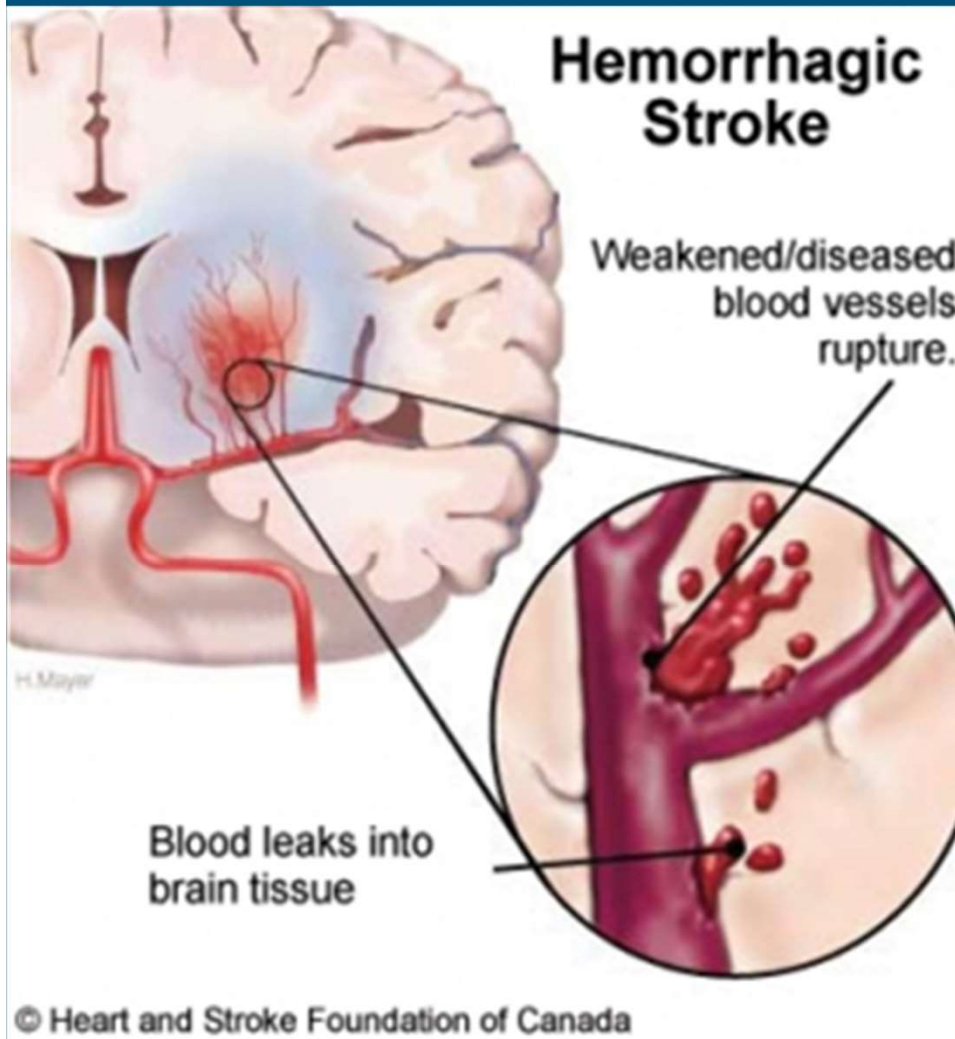
- V** - Vascular (Stroke -Carotid/Vertebral Dissection)
- I** - Inflammatory (ADEM/Migraine/Depression/TBI)
- T** - ***Traumatic (Blunt/Penetrating/Shaking/Sound blasts)***
- A** - Anoxic (Cardiopulmonary arrests/Toxic Inhalation)
- M** - Metabolic (Diabetes/Hypothyroid...)
- I** - Infectious (Encephalitis/AIDS...)
- N** - Neoplastic (Primary or Metastatic)
- D** - Demyelinating (Multiple Sclerosis)



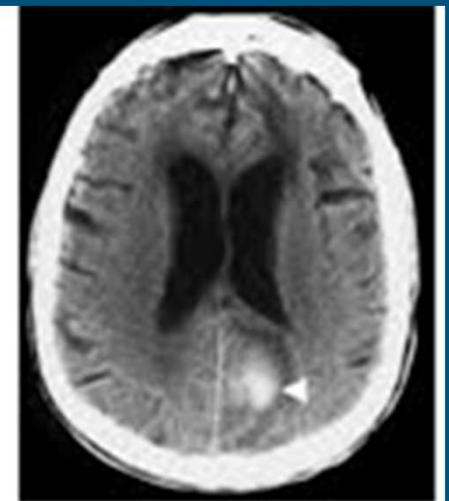




# Types of Brain Injuries-Vascular



Frontal Bleed



Occipital





# Trauma to the Blood Vessels

**Blunt/penetrating force** to the neck causing injuries to the Carotid or Vertebral arteries

e.g. **Carotid Artery Dissection** from seat-belts in a restrained driver/passenger during MVA



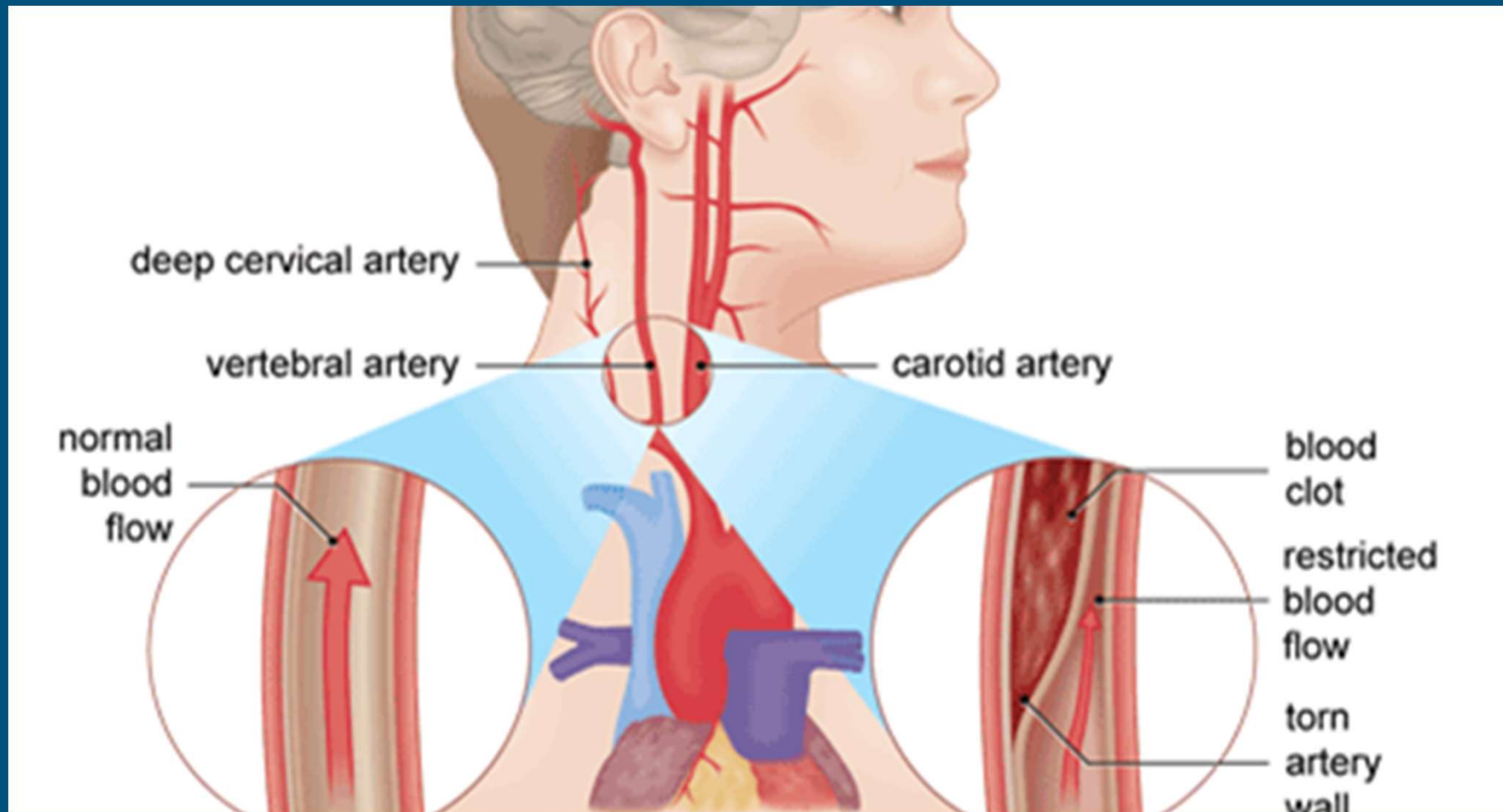
e.g. **Chiropractic maneuver** to the neck causing **Vertebral Artery Dissection**





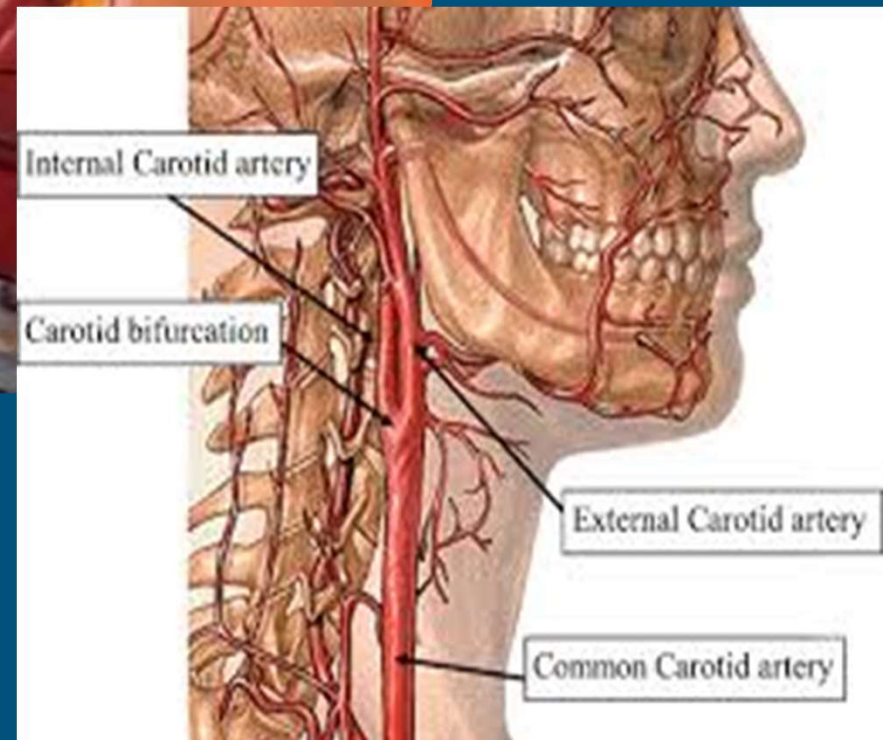
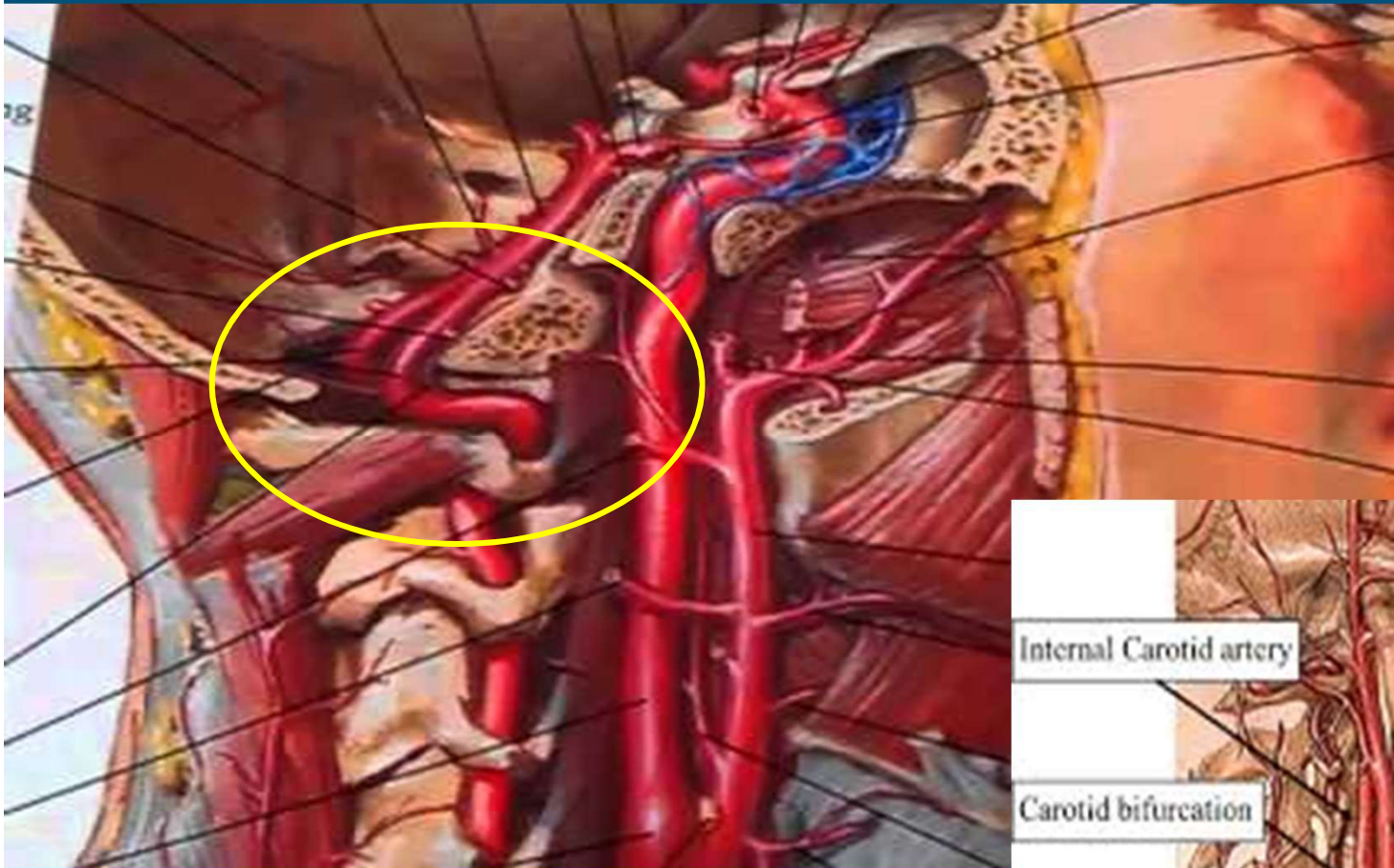


# Carotid Artery Dissection

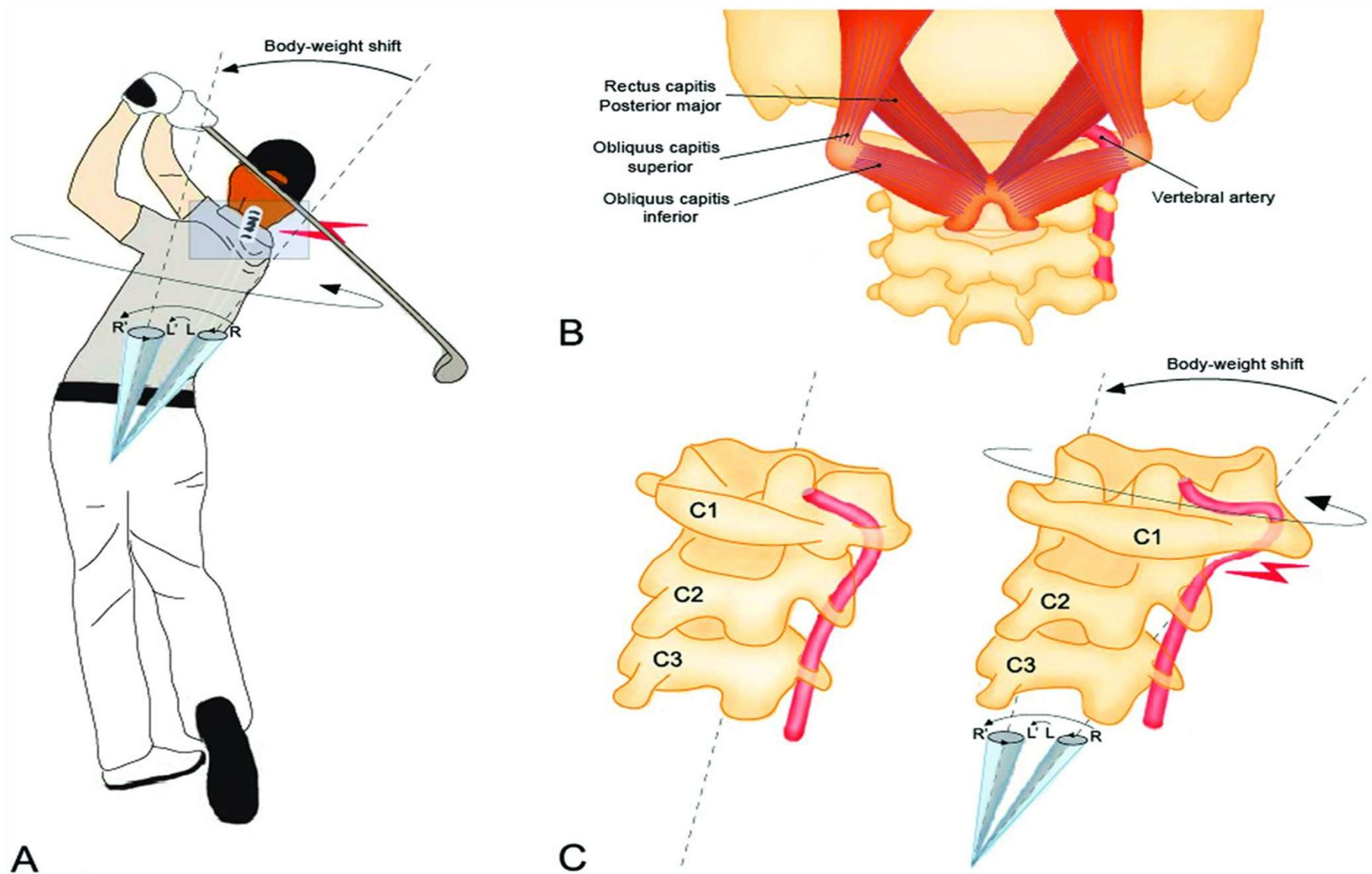




# Carotid and Vertebral Arteries







Preferential location for arterial dissection presenting as golf-related stroke. –  
M.H. Choi Nov 2013



# Vertebral Artery Injuries



- Some studies showed concurrent Vertebral Artery Dissections in up to 20% of blunt trauma to the cervical region; with an annual incidence of 1 to 1.5/100,000

-Redekop Can J Neuro Sc. 2008

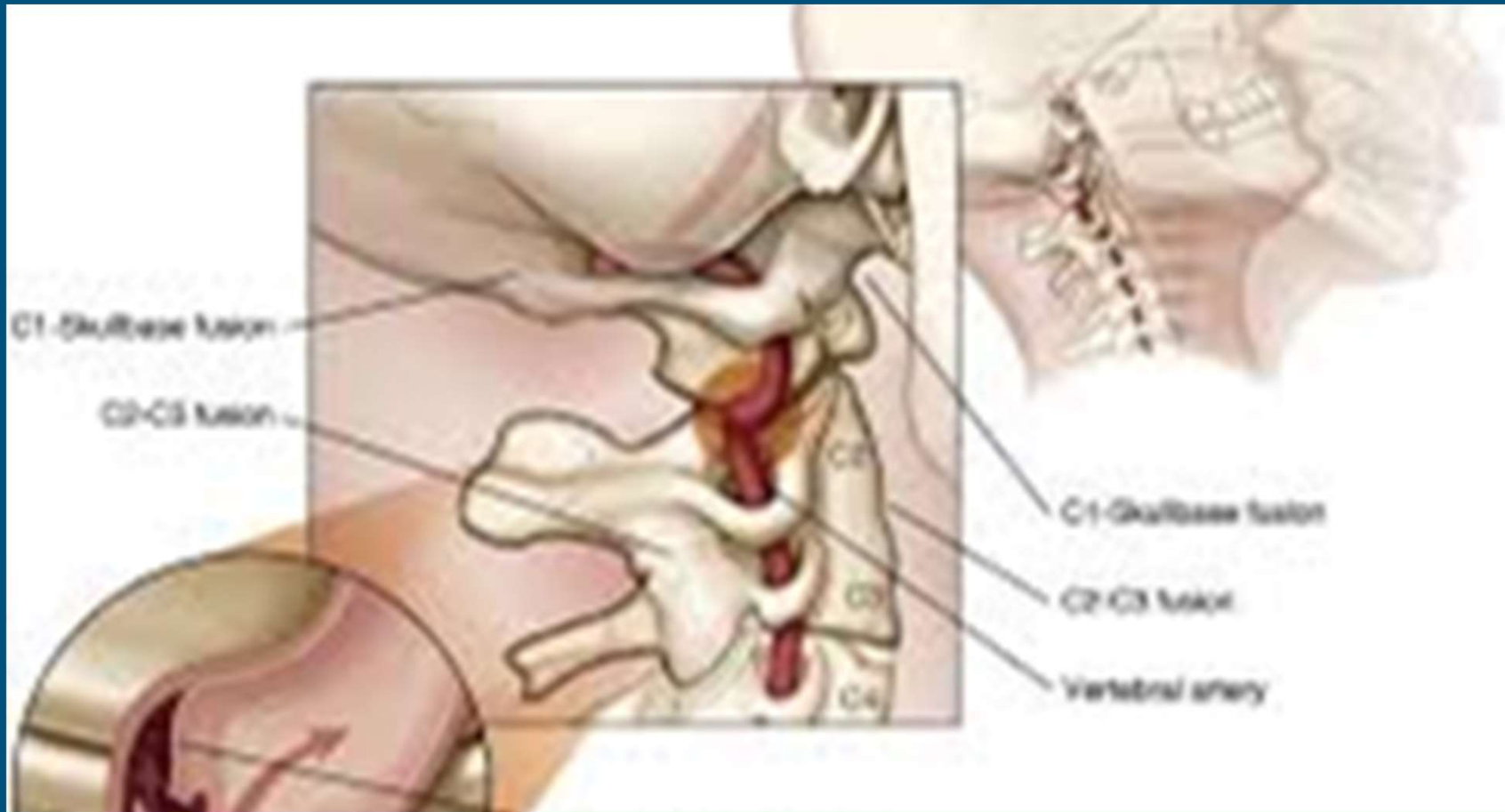
- whip-lash, motor vehicle crash, strangulations

- Incidence following chiropractic manipulations ranged from 1: 10,000 to 1 in 2 million
  - **“Vertebral Artery Dissection and Cerebellar infarction following chiropractic manipulation”.**  
Emergency Medicine Journal 2006
- Many are undiagnosed/unreported due to the insidious nature of symptoms and asymptomatic cases (collateral blood flow)





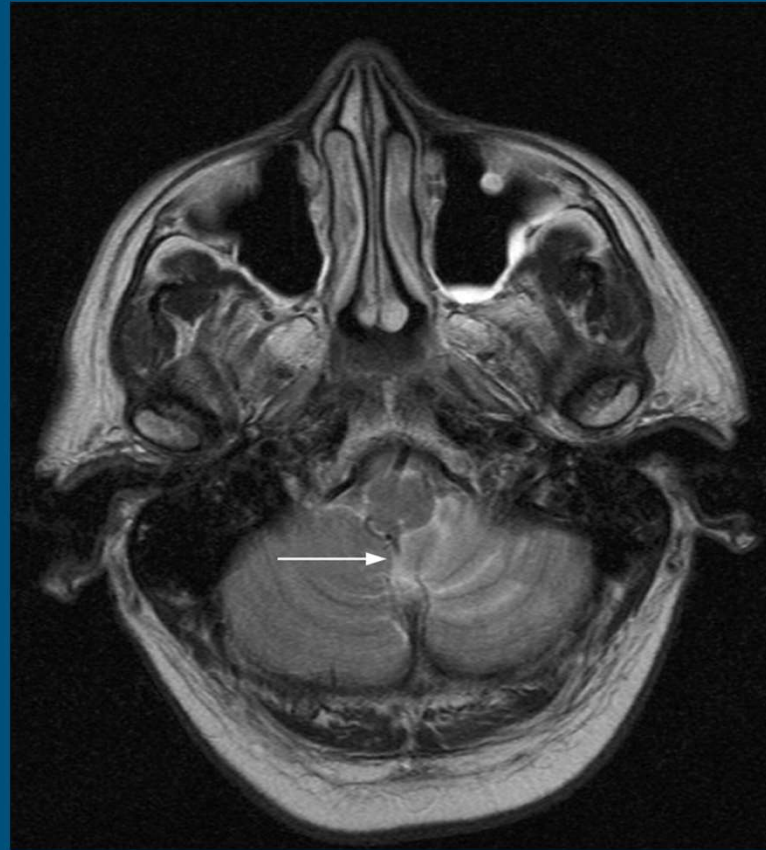
# Vertebral Artery Dissection





# Vertebral Artery Injuries :

## Cerebellar Infarct



**Brain MRI showed cerebellar stroke  
(CT Head was normal)**



# Focused Cerebellar Examination: Coordination



- Gait, Posture & Balance : Romberg's, truncal ataxia, tandem walk (dynamic balance)
- Ocular movements : nystagmus, saccades
- Speech: slurring, staccato/telegraphic speech
- Pronator drift & rebound test
- Finger-nose, hand slap
- Heel-shin
- Muscle tone





# Cerebellar Signs

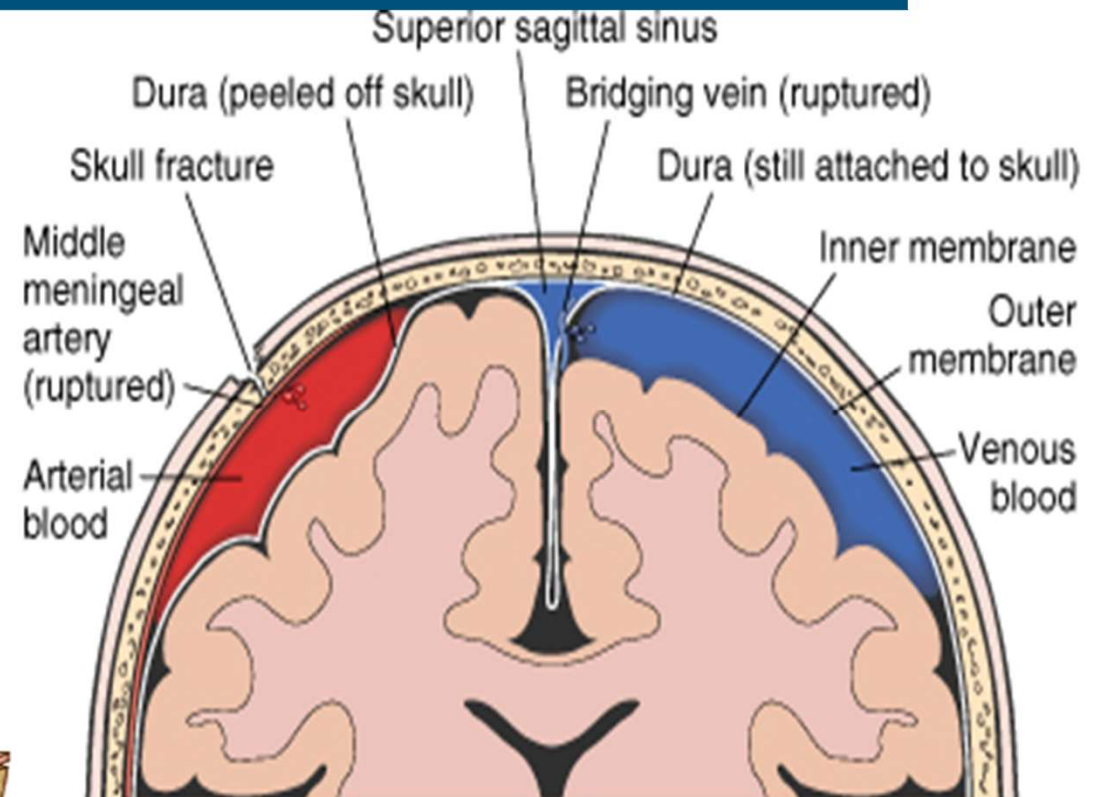
- **D** Dysdiadochokinesis & Dysmetria
- **A** Ataxia
- **N** Nystagmus
- **I** Intention tremor
- **S** Slurred or Staccato speech
- **H** Hypotonia



# Types of Brain Hemorrhage



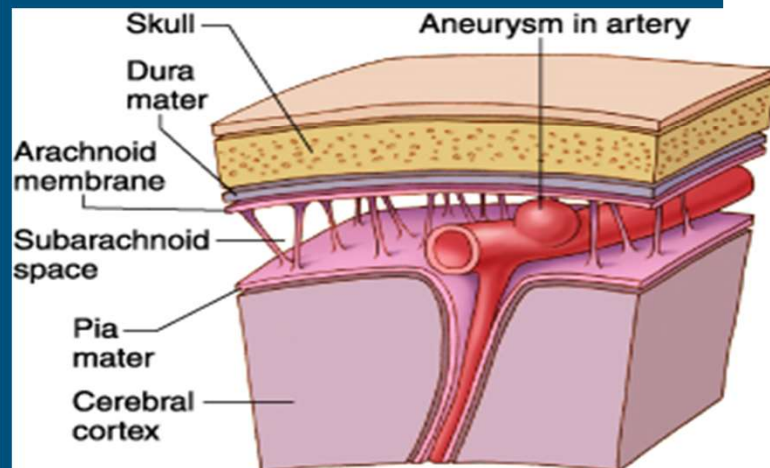
- Epidural (arterial)
- Subdural (venous)
- Subarachnoid (arterial)



A. Epidural hematoma

B. Subdural hematoma

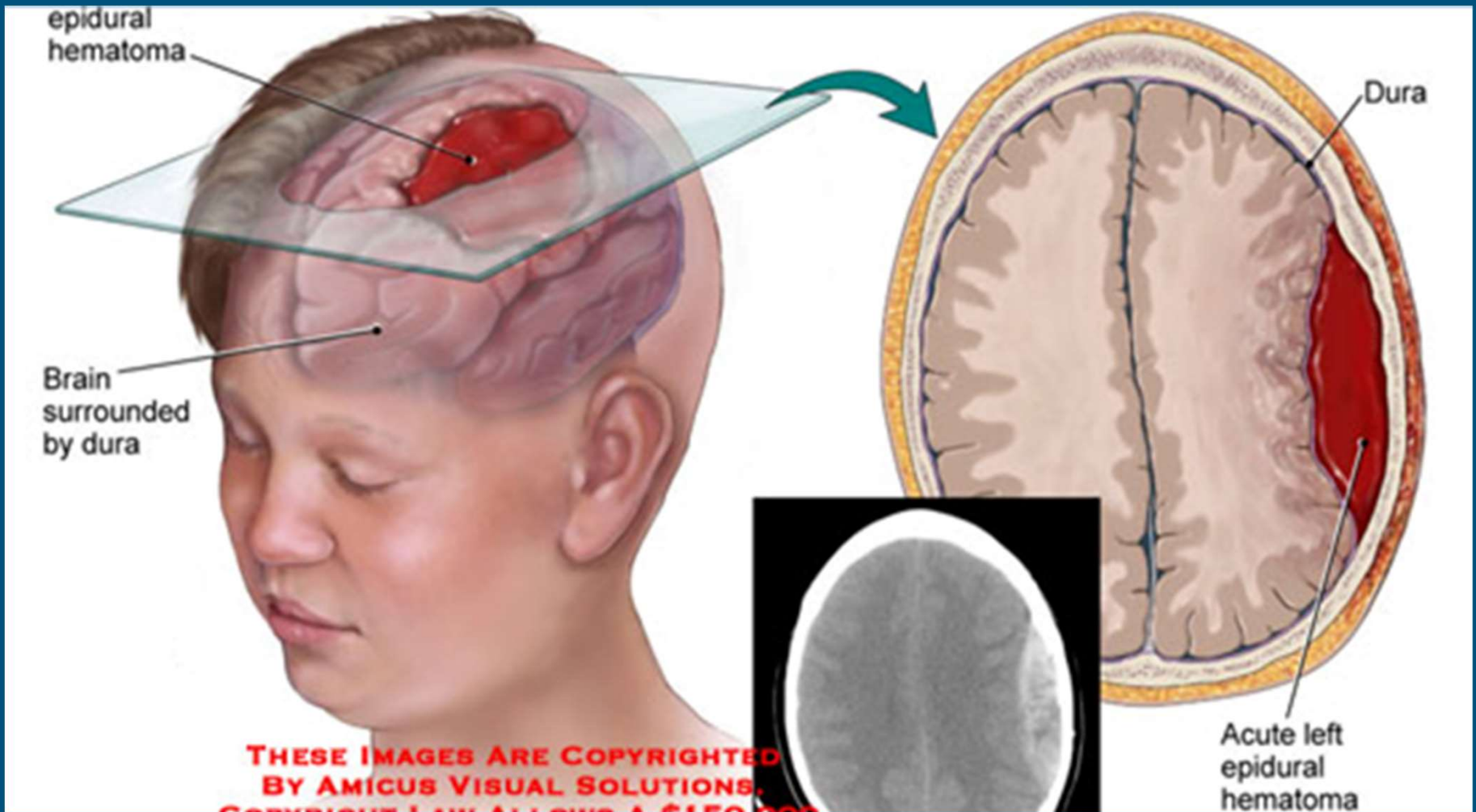
Elsevier Ltd. Kumar et al: Basic Pathology 7E [www.studentconsult.com](http://www.studentconsult.com)







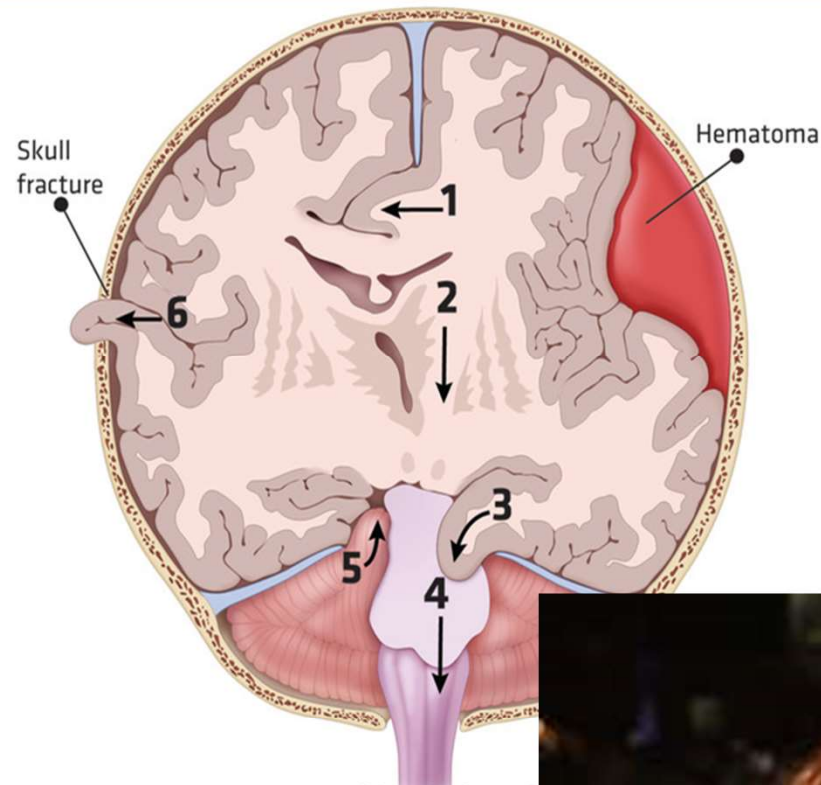
# Epidural Hematoma







# Epidural Bleed and Herniation



## Types of brain herni

- |              |                   |
|--------------|-------------------|
| 1) Cingulate | 4) Cerebellar     |
| 2) Central   | 5) Upward         |
| 3) Uncal     | 6) Transcalvarial |



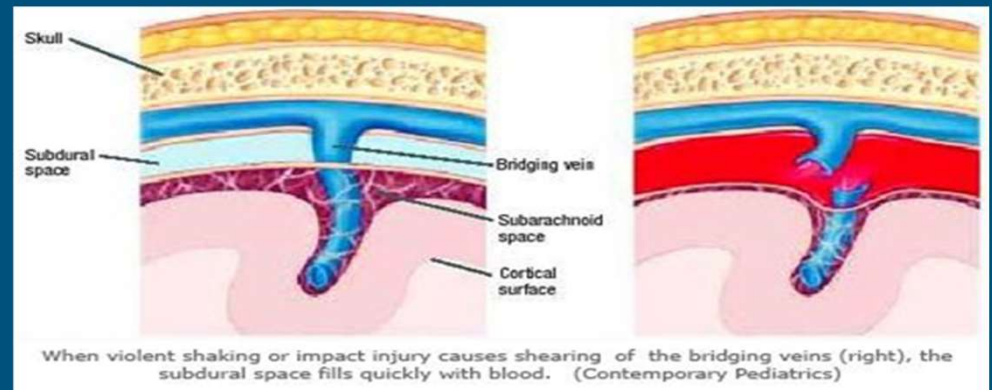


# Subdural Hematoma – Causation?



**Trauma** - Sudden blow to the head causes tearing of the subdural veins... But

---> Tiny tiny veins can bleed **spontaneously**



Factors for spontaneous bleeds that may **not be related to accident**

**Elderlies** are at risk for **spontaneous subdural bleeds** due to age/lifestyle related shrunken brain causing the tiny veins to be more stretched and susceptible to shearing force; poor balance increase risk of falling/tripping

People with bleeding disorders or taking **blood thinners** (aspirin, NSAIDs, Plavix, etc.)



# Subdural Hemorrhage : consider causation



## Alcoholics => Brain Shrinkage + Falls

- most typically under-report the amount of alcohol and incidence of falling (look into liver function/labs, clinical signs)

Incidence of “spontaneous” SDH is increasing and under-recorded

Other Lifestyle factors that contributed to brain atrophy

- heavy smoking, poor controlled diabetes, obesity



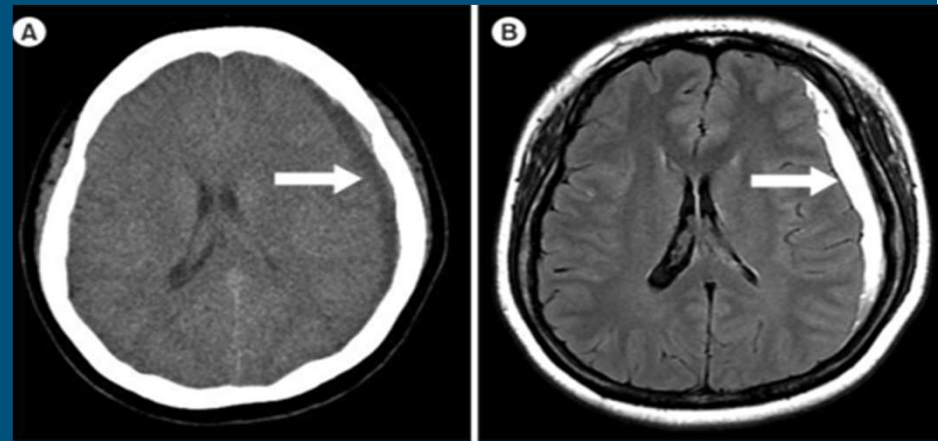
# Incidence of Subdural Hematoma



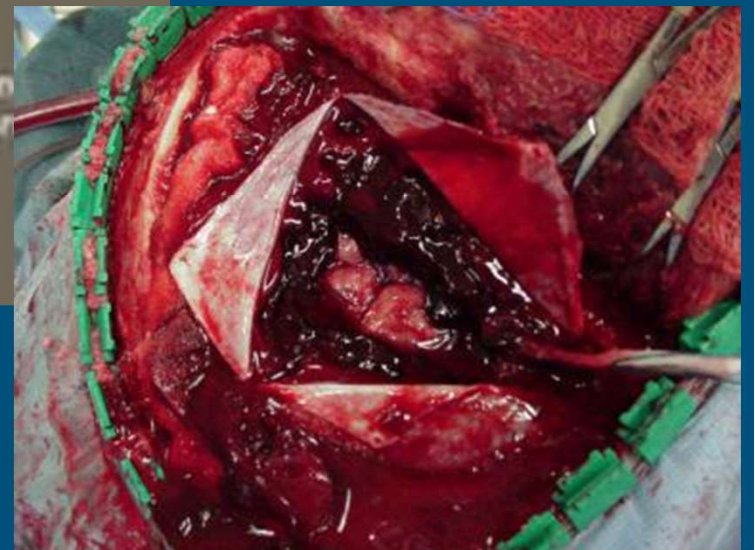
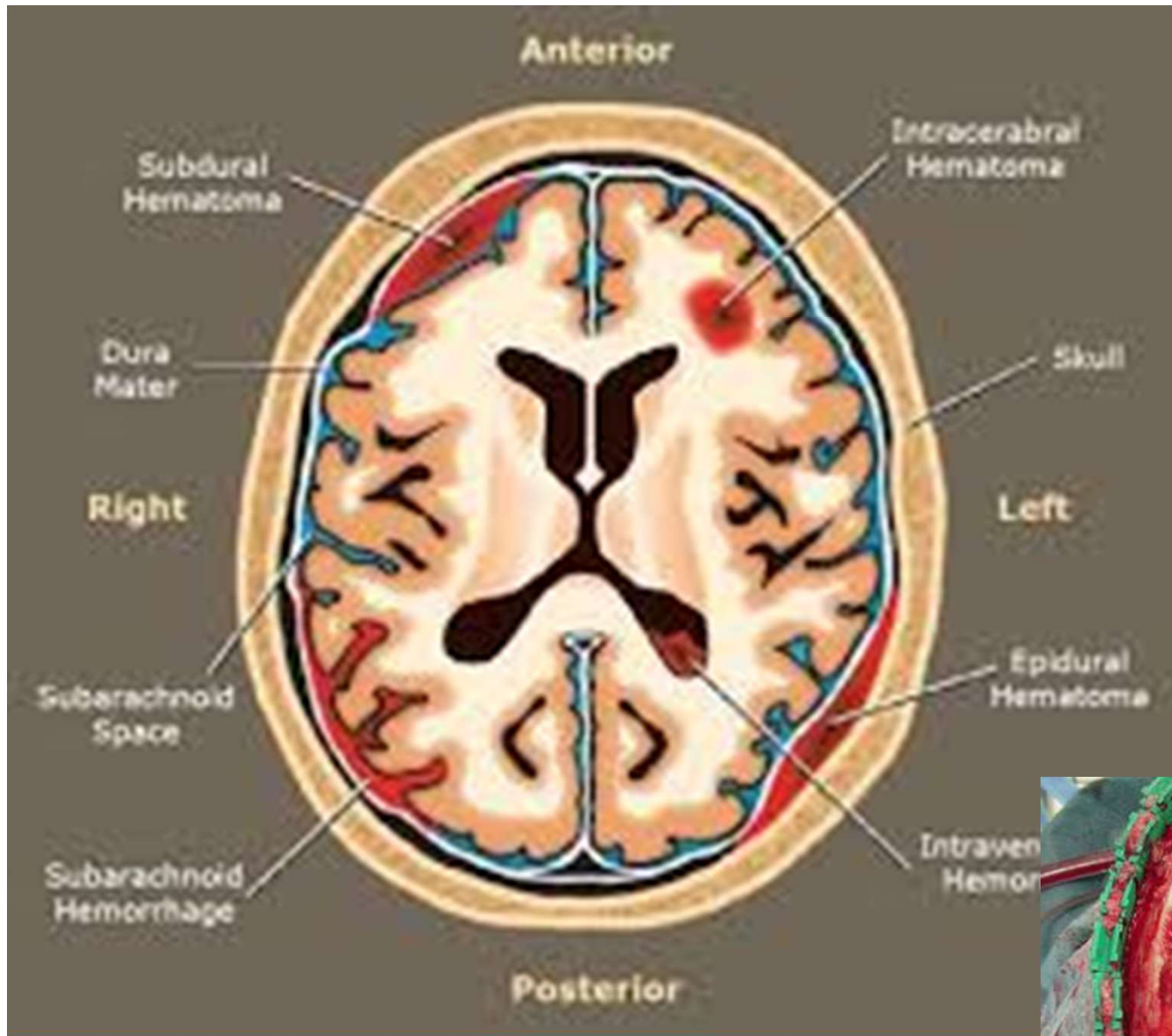
- 79.4 per 100,000 unique visits from 2000 – 2012
- Incidence of chronic subdural hematoma increases with aging population
- Projected approximately 60,000 Chronic Subdural Hematoma each year by 2030

- “Actual and projected incidence rate for chronic subdural hematomas in the U.S. Veteran Administration Hospital and civilian populations”

Neurosurgery 2015









# Traumatic Brain Injuries (TBIs)

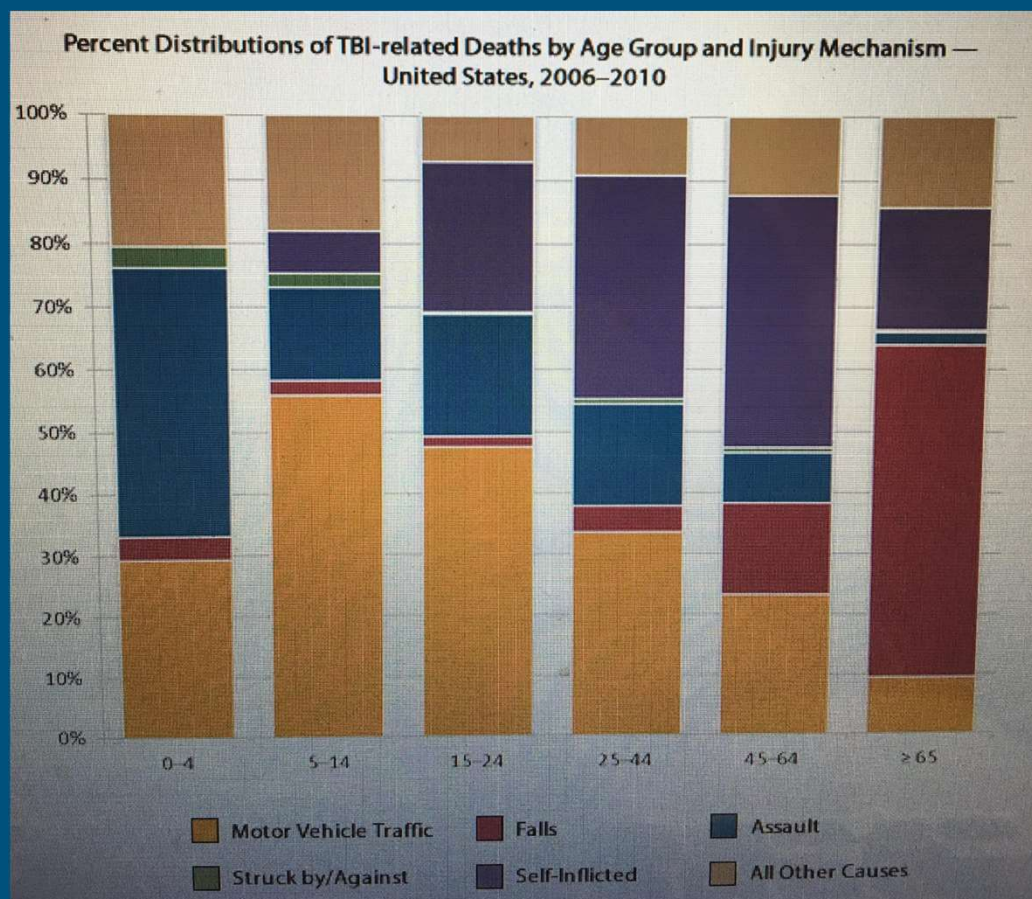


**CDC data:**

**In 2014,**

**about 2.87 million TBI-related ER visits, hospitalization and death.**

**The actual occurrence was much higher, as it did not include many who were seen in out-patient clinics or did not receive medical care. This number also did not include those treated in DoD/VA.**



*CDC: Get the Facts: Facts and Data TBI*



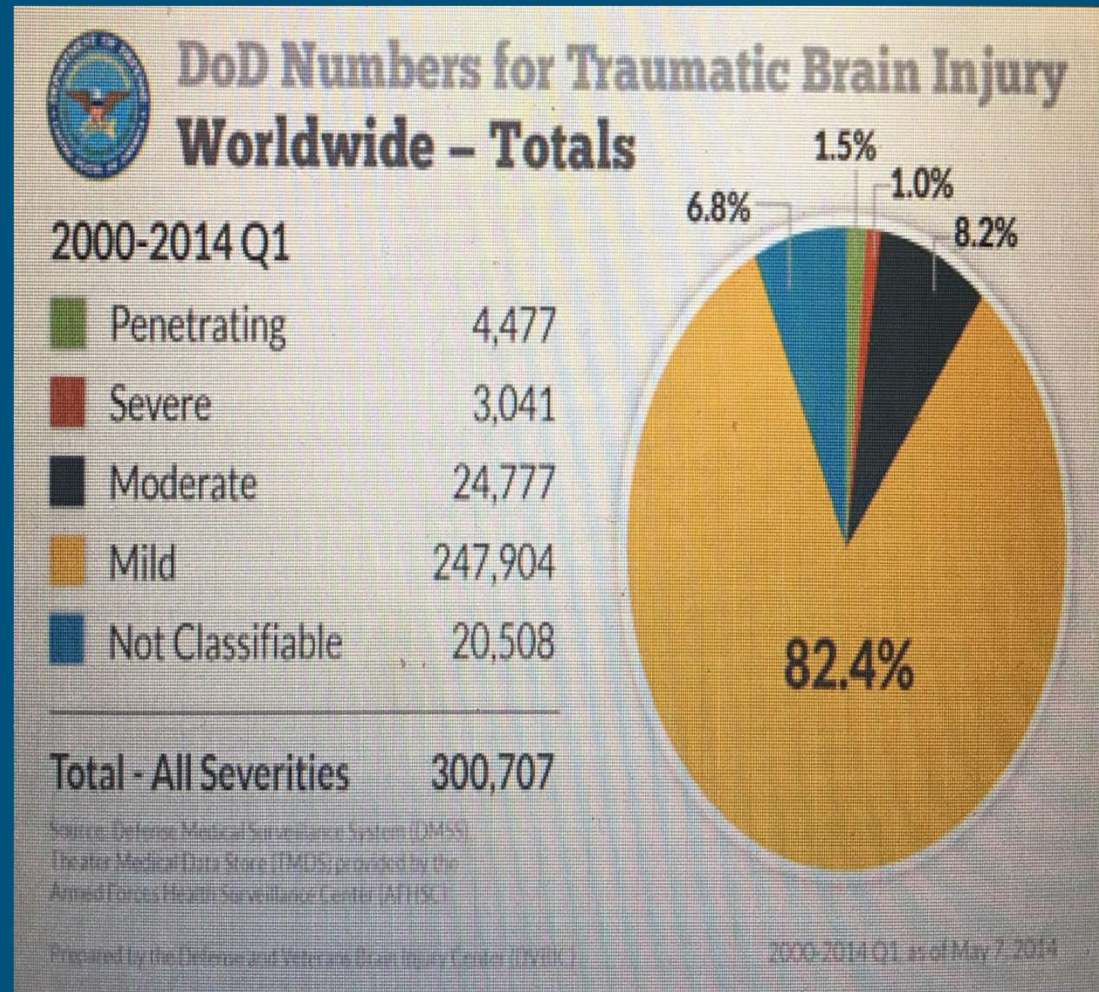
# Severity of Traumatic Brain Injuries



“mTBI” accounts for 80% - 90% of all TBIs

**“Concussion”**

**= mild Traumatic Brain Injury (mTBI)**





# Definitions of Concussion (mTBI)



- National Institute of Neurological Disorders and Stroke (NINDS)
- American Academy of Neurology (AAN) Guidelines for Management of Sports Concussion (mTBI)
- American Medical Association (AMA)
- US Centers for Disease Control and Prevention (CDC)
- World Health Organization (WHO)
- Defense and Veterans Brain Injury Center Working Group (DVBIC)





# National Institute of Neurological Disorder & Stroke (NINDS)

“Traumatic brain injury (TBI), often referred to as acquired brain injury or simply head injury, occurs when a *sudden trauma causes damage to the brain.*”



# American Medical Association (AMA)



- A concussion is
  - “a clinical syndrome characterized by the ***immediate*** and ***transient*** post-traumatic impairment of neural function such as alteration of consciousness, disturbance of vision or equilibrium etc. due to brainstem involvement.”





# US Centers for Disease Control and Prevention (CDC)

“Traumatic Brain Injury (TBI) is caused by a bump, blow or jolt to the head or a penetrating head injury that disrupt the normal function of the brain. Not all blows or jolts to the head results in a TBI.”



# World Health Organization (WHO)



One or more of the following

- Confusion or disorientation
- LOC < 30 minutes
- Post Traumatic Amnesia < 24 hours
- Transient neurological deficits:
  - Seizure & non-surgical intracranial lesion

*International Statistical Classification of Diseases and Related Health Problems (ICD-10)*
- Glasgow Coma Scale score 13-15 within 30 minutes



# American Academy of Neurology (AAN) Guidelines



- Concussion is a ***trauma-induced alteration in mental status that may or may not involve loss of consciousness***
- The severity of TBI is defined by the acute injury characteristics, ***not by the presence, absence, or severity of symptoms at random times following the trauma.***
- **Confusion** and **amnesia** are the hallmark complaints with a concussion.
- Concussions may be subdivided into ***mild, moderate*** and ***severe***.



# Defense and Veterans Brain Injury Center Working Group



- “Mild TBI in military operational setting is defined as an injury to the brain resulting from **an external force** and/or **acceleration/deceleration** mechanism from an event such as a **blast, fall, direct impact** or **motor vehicle accident** which causes an *alteration* in mental status typically resulting in temporally related onset of symptoms such as : headache, nausea, vomiting, dizziness, balance problems, fatigue, trouble sleeping, sleep disturbance, drowsiness, light/noise sensitivity, blurred vision, difficulty remembering, and/or difficulty concentrating.”



# Expert panel position statement of 2010

The Defense Centers of Excellence for Psychological Health and Traumatic Brain Injury, the National Institute of Neurological Disorders and Stroke (NINDS), the Department of Veterans Affairs (DVA), and the National Institute on Disability and Rehabilitation Research (NIDRR)

*“TBI is defined as an alteration in brain function, or other evidence of brain pathology, caused by an external force”*

*Alteration in brain function* is defined as any **one** of the following clinical signs:

- Any period of loss of or a decreased level of consciousness
- Any loss of memory for events immediately before/retro- grade amnesia or after the injury/anterograde amnesia i.e. Posttraumatic Amnesia (PTA)
- Neurologic deficits (weakness, loss of balance, change in vision, dyspraxia, paresis, paralysis, sensory loss, aphasia, etc.)
- Any alteration in mental state at the time of the injury (confusion, disorientation, slowed thinking, etc.)



In regard to neuro-psychiatric manifestation after a brain trauma, the panel offered the following statement:

---

*“TBI has been diagnosed when the symptoms and signs are closely temporally related to the insult. However, we need to recognize that clinical manifestations may be delayed. This issue is particularly relevant for neuropsychiatric sequelae (depression, impulsivity, apathy, etc.), which may only be documented some time after the insult, and may also be the consequence of non-TBI etiologies”*



# Common symptoms of Concussion



- **Physical** Symptoms (headache, dizziness, blurry vision, balance problem, noise sensitive, light sensitive, and/or fatigue)
- **Emotional** Symptoms (irritability, sadness, nervousness, and/or emotionally labile : Pseudobulbar Affective Disorder/PBA)
- **Cognitive** Symptoms (poor concentration, poor memory, and/or feeling mentally foggy)

Sleep disturbances

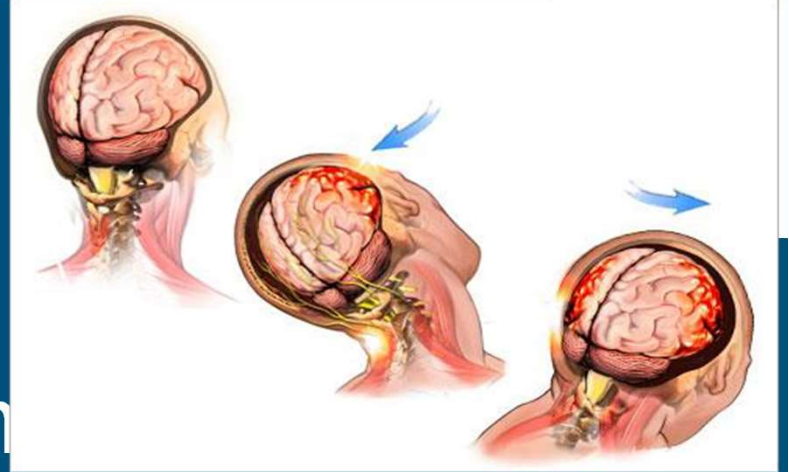
**>75% -90% resolved completely after 4 weeks**

**but... even 10% of the > 2.8 million/year : 280,000 concussed individuals/year in the US**



# *Whip-Lash*

## Acceleration/Deceleration



- Motor Vehicle Crash (with or without direct head impact)
- Workplace Injury
  - Altercation
  - Slip and Falls
  - Workers walk into hard surfaces, trip over objects
  - High acceleration impact; water/air pressure to chest/body



The brain is very soft, with consistency between jelly and butter



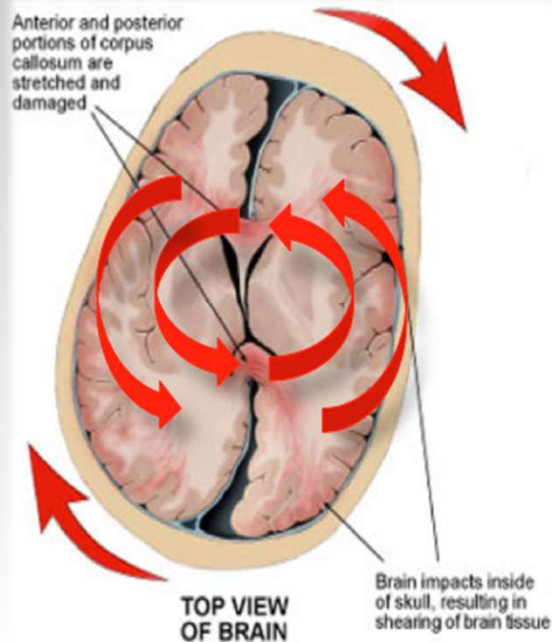


# Rotational Forces



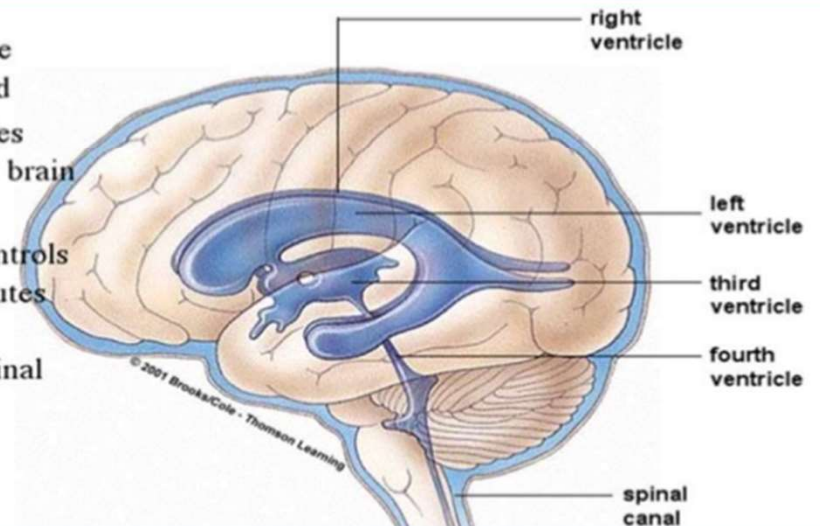
## Rotational forces produces diffuse injury

- Concussion
- Axonal damage
- Hemorrhage



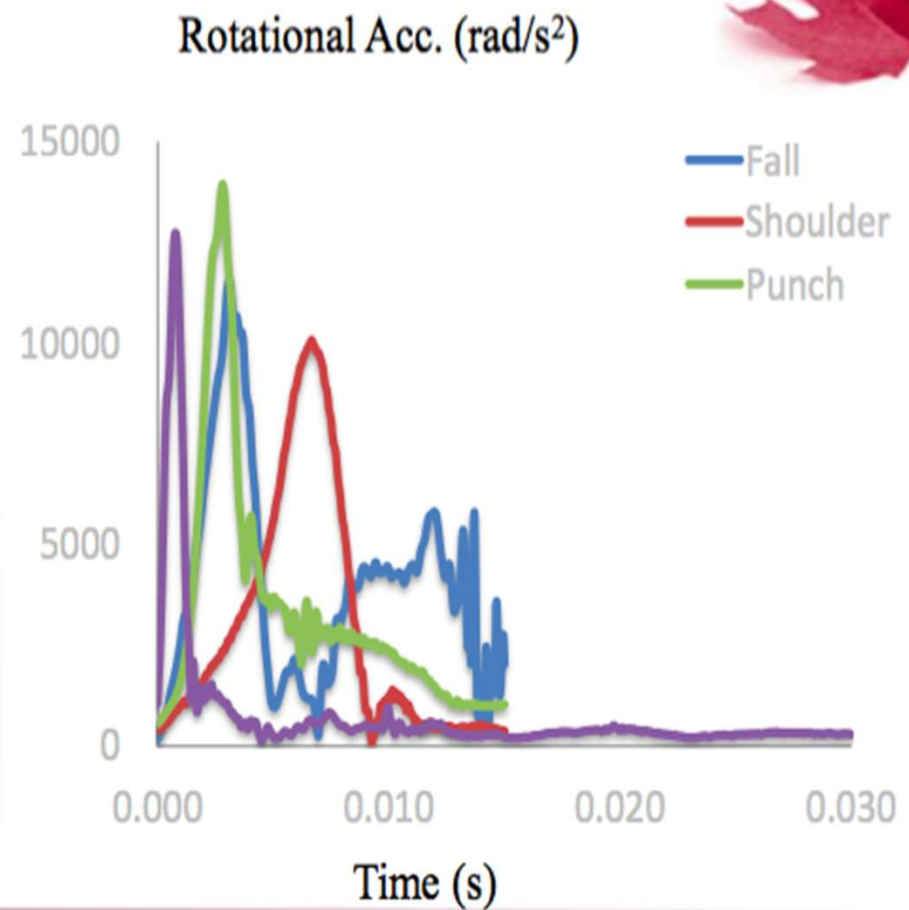
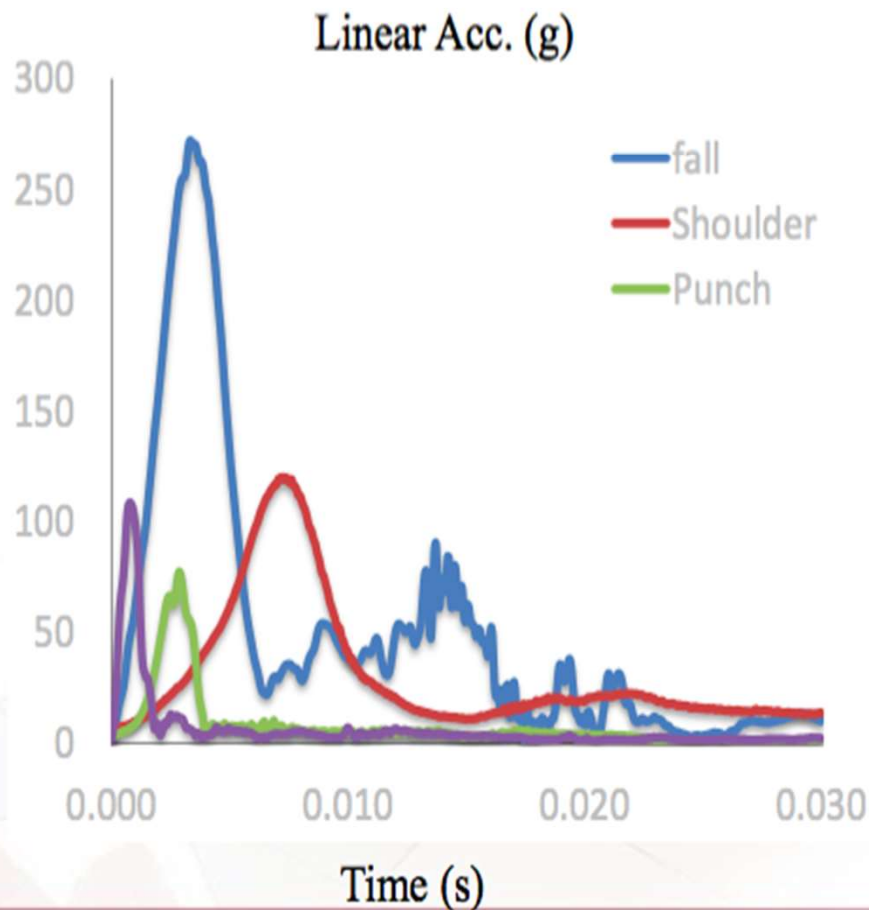
The cerebrospinal Fluid [CSF] is a clear, colorless transparent, tissue fluid present in the cerebral ventricles, spinal canal, and subarachnoid spaces.

Surrounds the spinal cord  
Fills ventricles within the brain  
Blood-brain barrier controls which solutes enter the cerebrospinal fluid





# Head impact event and Dynamic response



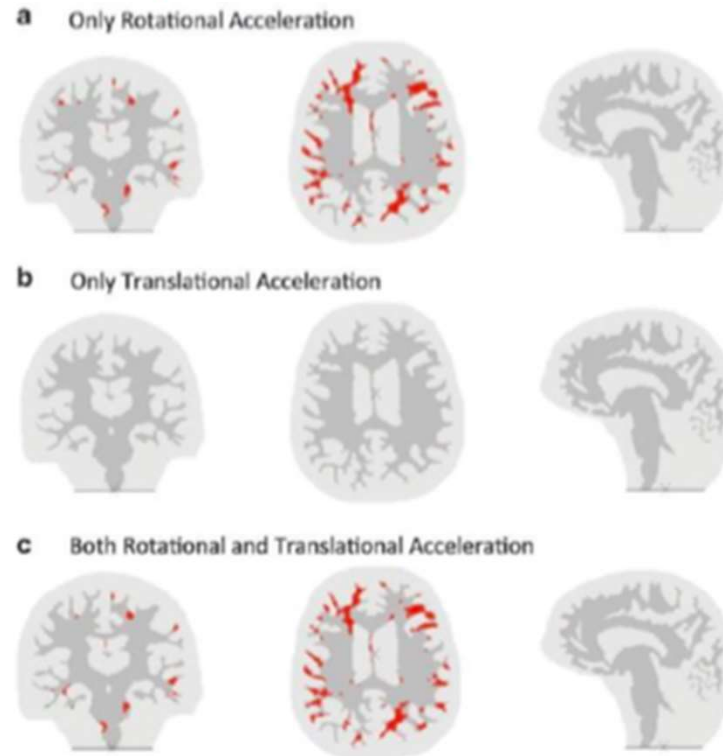
uOttawa

T.B. Hoshizaki 2018

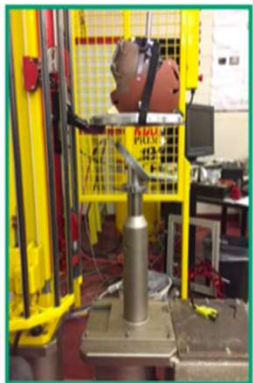
Neurotrauma Impact Science Laboratory



# Relationship between linear and rotational acceleration and Maximum Principal Strain (John Hopkins FE model, Crosby)



## Helmet Impact Certification Testing



Rotation (cycling)



Rotation (football)

Linear (all)

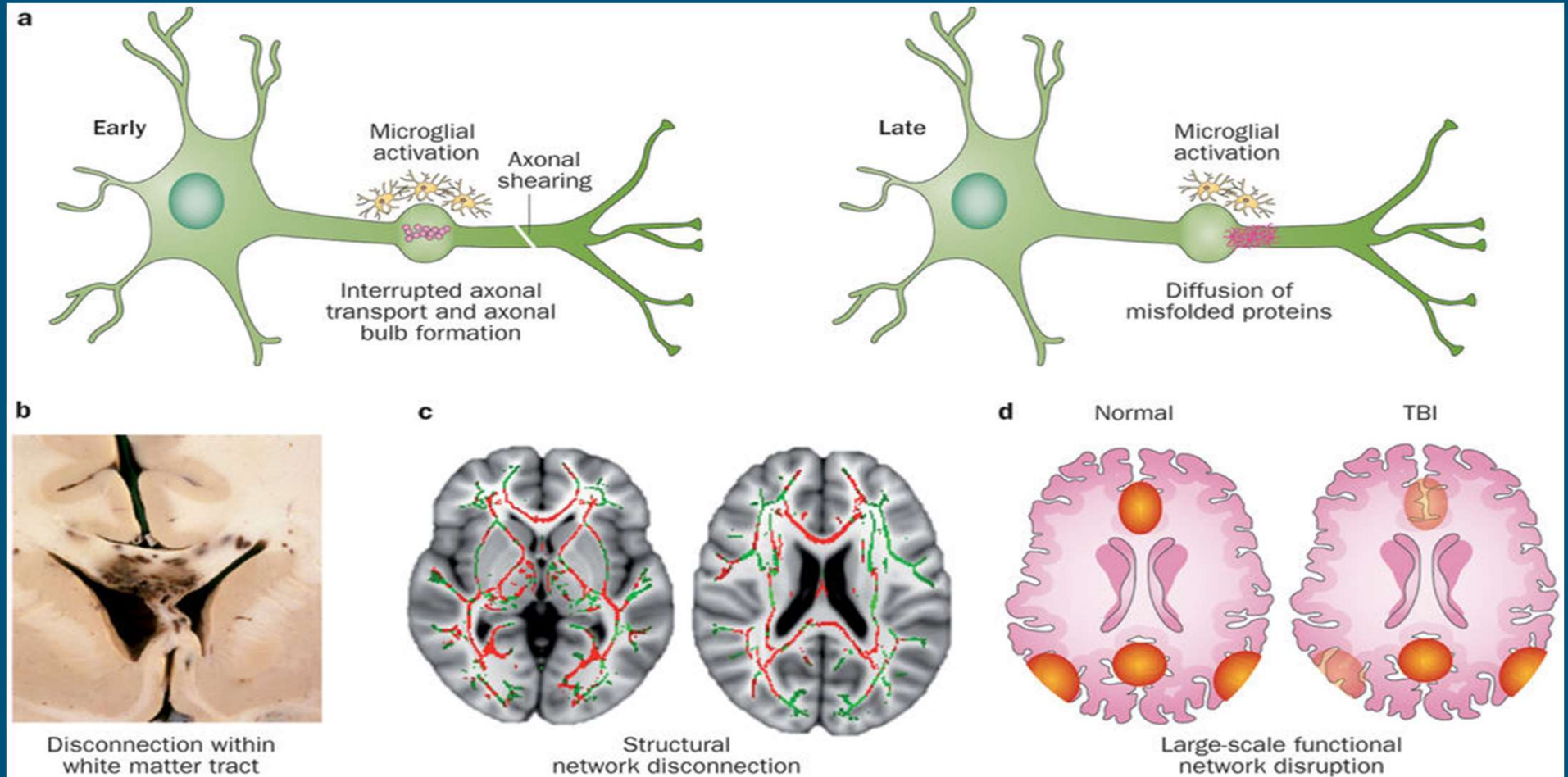
and Ramesh K.T., "A multiscale  
ing axonal damage under inertial loading of  
, 30(2), 102-118, 2013.

T.B. Hoshizaki 2018

**Dr. Hoshizaki - Neurotrauma Impact Science  
Laboratory**



# Diffuse Axonal Injury (DAI)



## Secondary Injury (Late effects)

Wallerian Degeneration (cell death due to axonal injury)

Neuroinflammation



# Has he sustained a concussion?





# Take Away Message...



- There is NO one specific test to diagnose a Concussion or Post-concussive Syndrome!
- Concussion or Post-Concussive Syndrome is a clinical diagnosis:
  - story +
  - symptoms +
  - signs +
  - studies (available diagnostic tools)



# Can you see a concussion?

## Imaging studies





# Limitations of Conventional Testing



One cannot see a concussion from a Head CT or Brain MRI.

Routine imaging with CT and MRI scans are typically normal and **do not exclude** concussion.

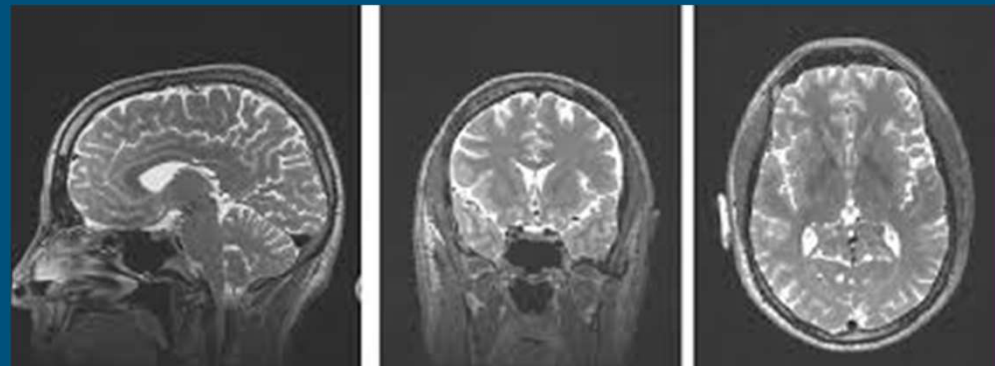
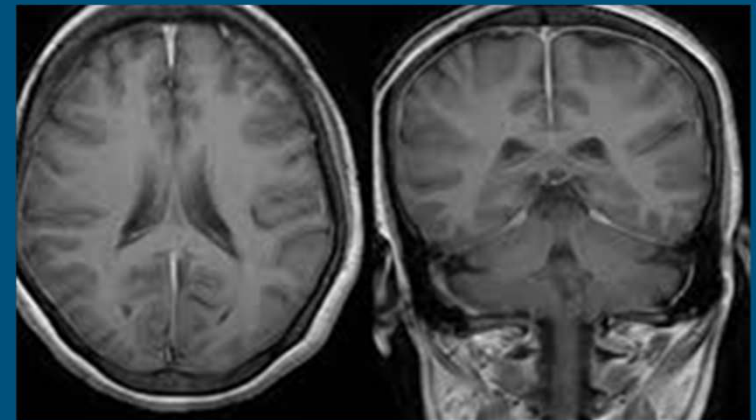
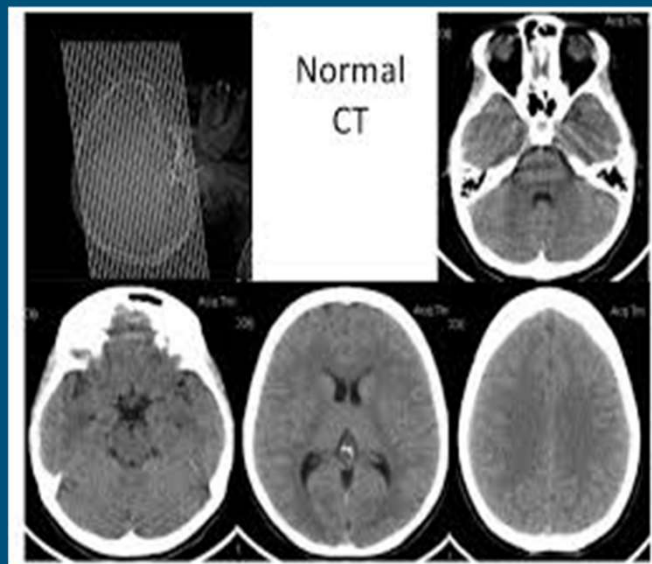
Conventional CT/MRI fail to adequately detect the subtle structural (intracellular damage) disruption in the neuro-metabolic cascade and functional disruptions affecting the concussed brain.

**Concussion/mTBI is an invisible injury**





80-90% of TBI showed  
normal CT & MRI



**Conventional imaging like CT & MRI fail to identify  
microbleeds, axonal shearing, blood-brain barrier disruptions,  
intracellular damages, etc..**



# CT Head Imaging



- Computer Tomography (CT) – helpful in skull fractures, subdural, epidural or intracerebral hemorrhages.
- Widely available and fast

→ But...CT scan within 3 hours of injury may miss certain intracranial bleeds

\*Yield: 5% of patients with mTBI (GCS =15)  
have pathologic findings on CT



Useche JN et al. Neuroimaging Clinics of North America 2018.28:15-29



# Brain MRI preferable to Head CT



## Magnetic Resonance Imaging Improves 3-Month Outcome Prediction in Mild Traumatic Brain Injury

Esther L. Yuh, MD, PhD,<sup>1,2</sup> Pratik Mukherjee, MD, PhD,<sup>1,2</sup> Hester F. Lingsma, PhD,<sup>3</sup>  
John K. Yue, BS,<sup>1,4</sup> Adam R. Ferguson, PhD,<sup>1,4</sup> Wayne A. Gordon, PhD,<sup>5</sup>  
Alex B. Valadka, MD,<sup>6</sup> David M. Schnyer, PhD,<sup>7</sup> David O. Okonkwo, MD, PhD,<sup>8</sup>  
Andrew I. R. Maas, MD, PhD,<sup>9</sup> Geoffrey T. Manley, MD, PhD,<sup>1,4</sup> and the  
TRACK-TBI Investigators

*Annals of Neurology*, 2013

Among concussed patients, up to 30% of normal CT scan demonstrated MRI changes

- Comparative Study of MR and CT scan imaging in cases of severe head injury. *Acta Neurochir. Suppl.* 1992

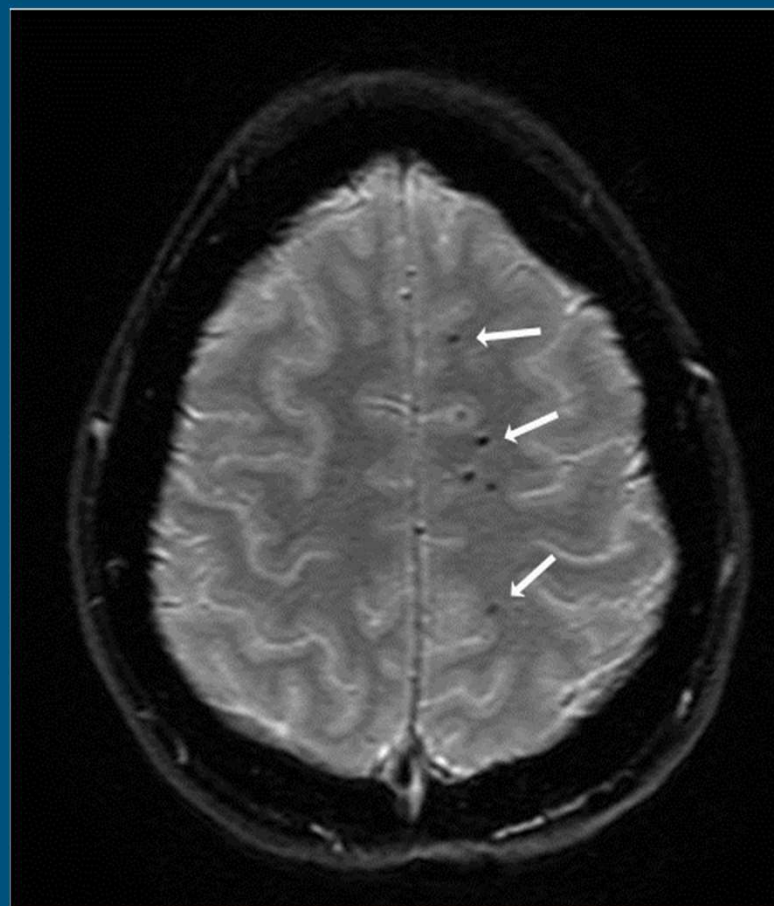




**Magnetic Images (MRI)** –may detect subtle petechial hemorrhages

- Old vs New blood
- Underlying/old intracerebral pathologies that are not related to trauma
- “brief MRI” protocol has been proposed to to be done within 48 hours of TBI : study showed abnormalities in 57% of patients with normal head CT

- Concussion Neuroimaging Consortium  
2014





# Advanced Neuro-imaging



- Susceptibility Weighted Imaging (**SWI**) can detect micro-hemorrhage
- Diffusion Tensor Imaging (**DTI**) shows promise in demonstrating edema and axonal injury

*(many delayed symptoms after TBI are partly caused by axonal shear causing incomplete neuronal transmission)*

- MR spectroscopy (**MRS**) can detect metabolic alterations
- Functional MRI (**fMRI**) can measure local changes in oxygen consumption in response to activities
- Resting state fMRI and Connectome Analysis

But... these are mostly offered in research facilities



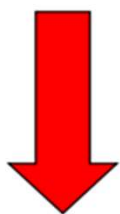
## LETTER

doi:10.1038/nature12808

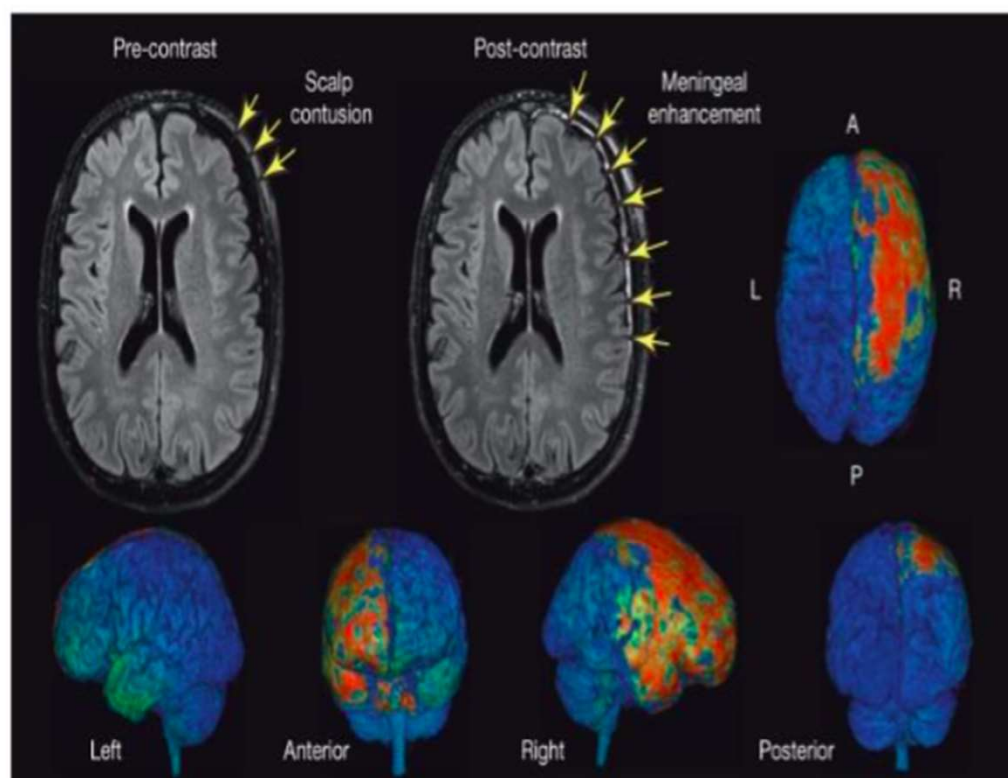
### Transcranial amelioration of inflammation and cell death after brain injury

Theodore L. Roth<sup>1</sup>, Debasis Nayak<sup>1</sup>, Tatjana Atanasijevic<sup>1</sup>, Alan P. Koretsky<sup>1</sup>, Lawrence L. Latour<sup>1</sup> & Dorian B. McGavern<sup>1</sup>

- 142 mTBI (GCS=15) <48hr
- LOC or PTA
- Negative 'parenchymal' CT



- Meningeal hemorrhage on CT in 12.7%
- Focal enhancement on post-contrast FLAIR in **48%** (+CT) and **37%** (-CT)



TL Roth *et al.* *Nature* 2014;505:223-228

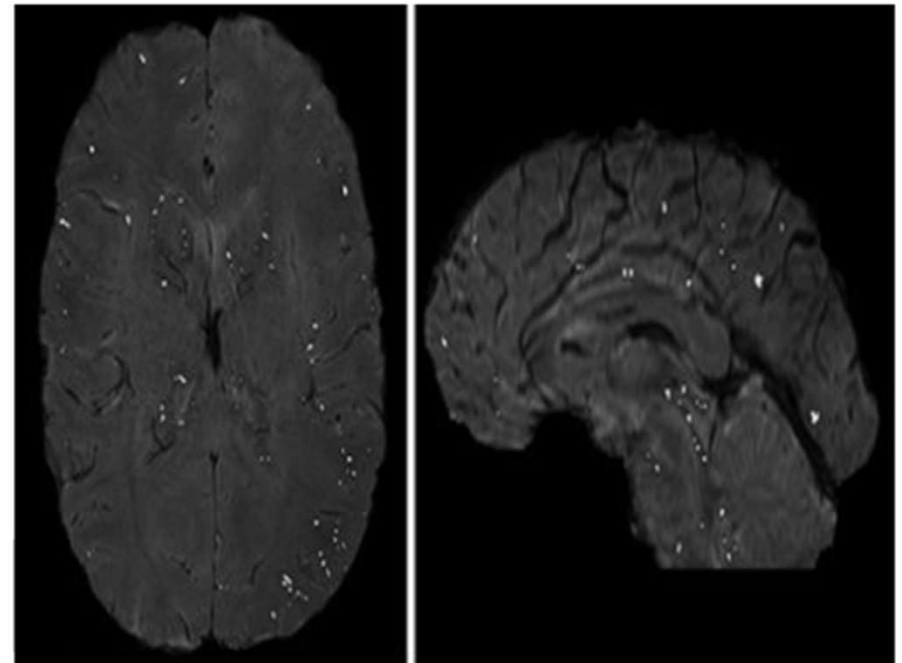


## Abnormal Susceptibility Weighted Imaging In Concussed Varsity Ice Hockey Players

45 university male and female ice hockey players underwent advanced SWI before/after season and after concussion

Significant increase in CMBs:

- 2 weeks after concussion
- Males vs females
- End of season in those without concussion



Helmer KG, et al. J Neurosurg 2014; 120:864–872.





# ***Subconcussion***

– “head impacts causing no immediate symptoms are associated with cellular perturbations resulting in micro-injury that, with cumulative exposure, might lead to late pathology”

--Christopher Giza, M.D. Department of Neurosurgery, BrainSPORT Program, Director NCAA.DoD

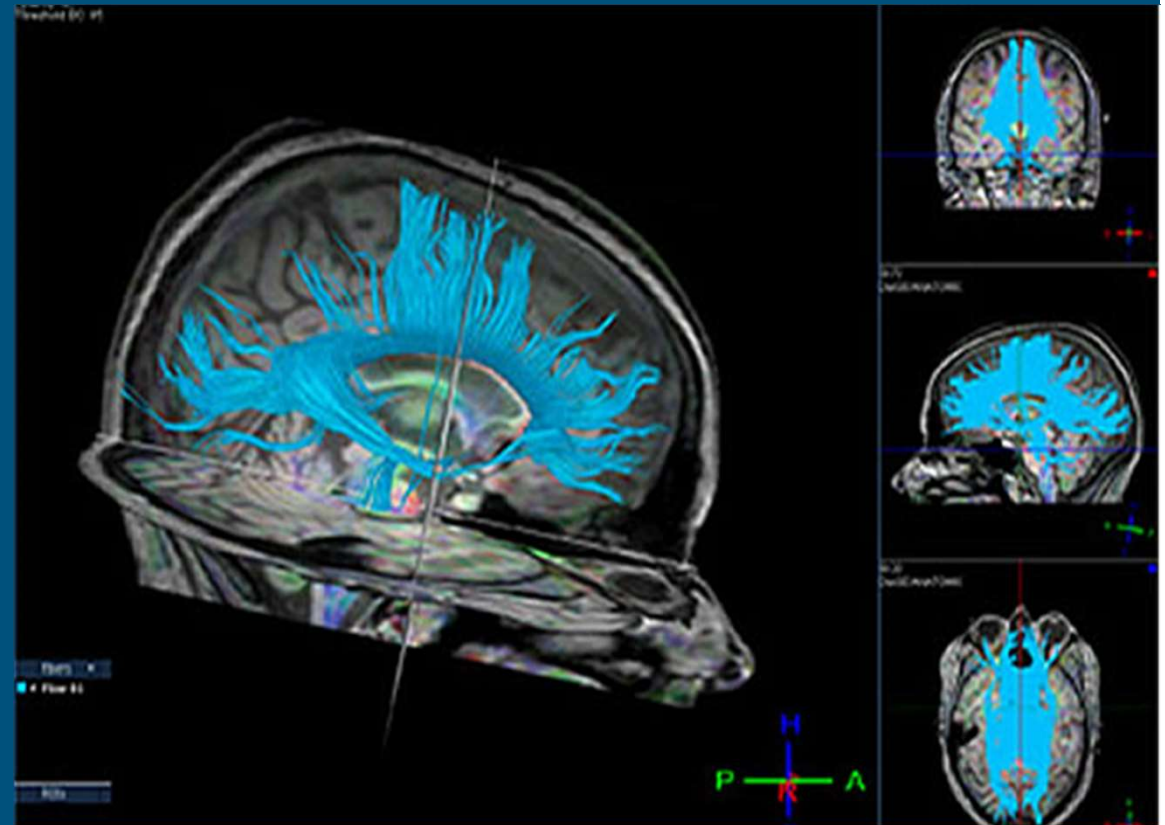


# Diffuse Tensor Imaging (DTI-MRI)



Diffusion weighted images (DWI) show movements of water in three directions  
Diffusion Tensor Images (DTI) show white matter tracts (axons); show movements of water in 6 directions

Diffusion Tensor Imaging (DTI) shows promise in demonstrating edema and axonal injury

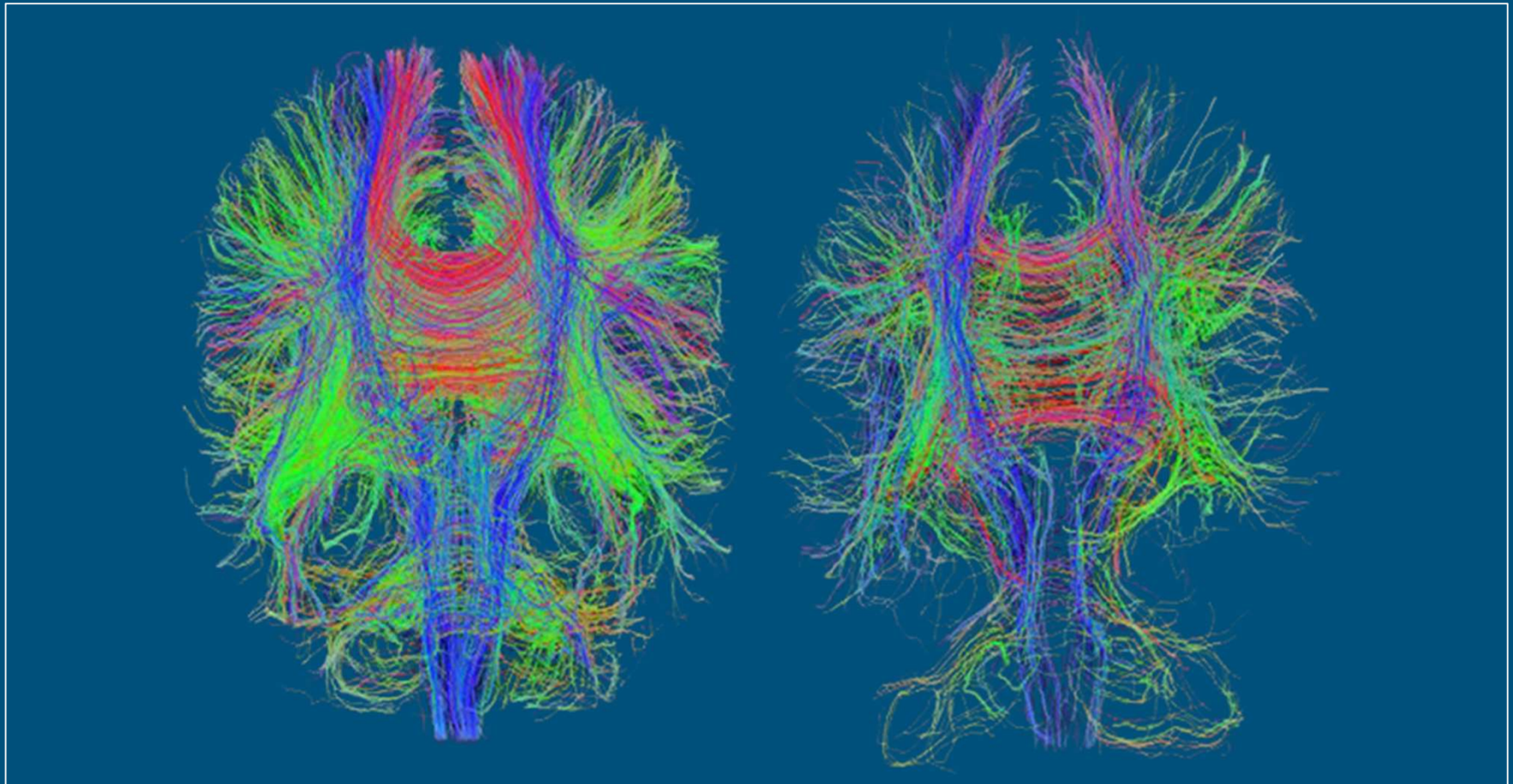


“Shake it and you break it” Steven Laureys, Director of the Coma Science Group TEDxLiege. 2016





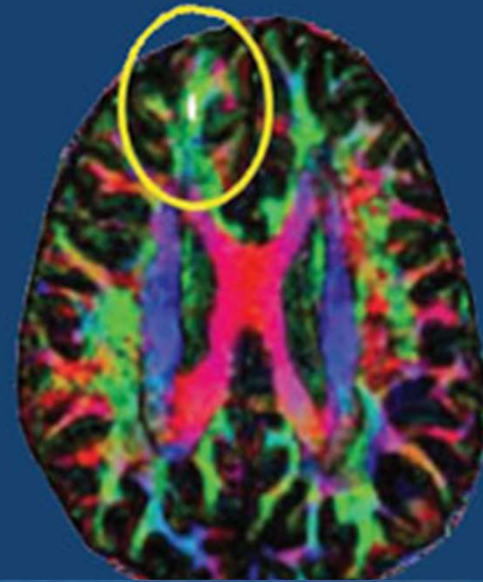
# DTI showing axons



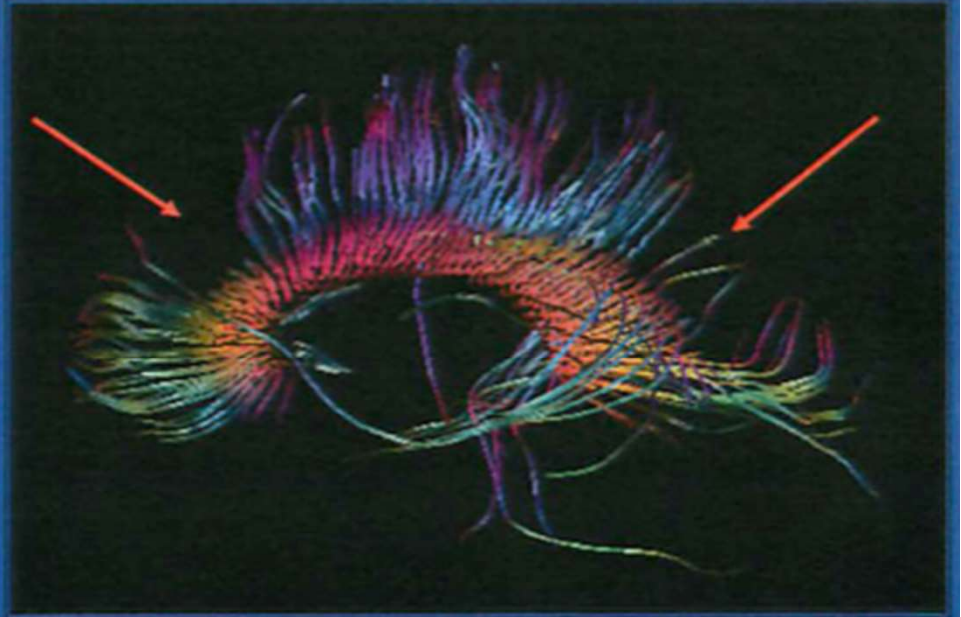


# DTI scan

Diffusion Tensor Imaging (DTI) can detect subtle Axonal Shears that were undetected in conventional MRIs.



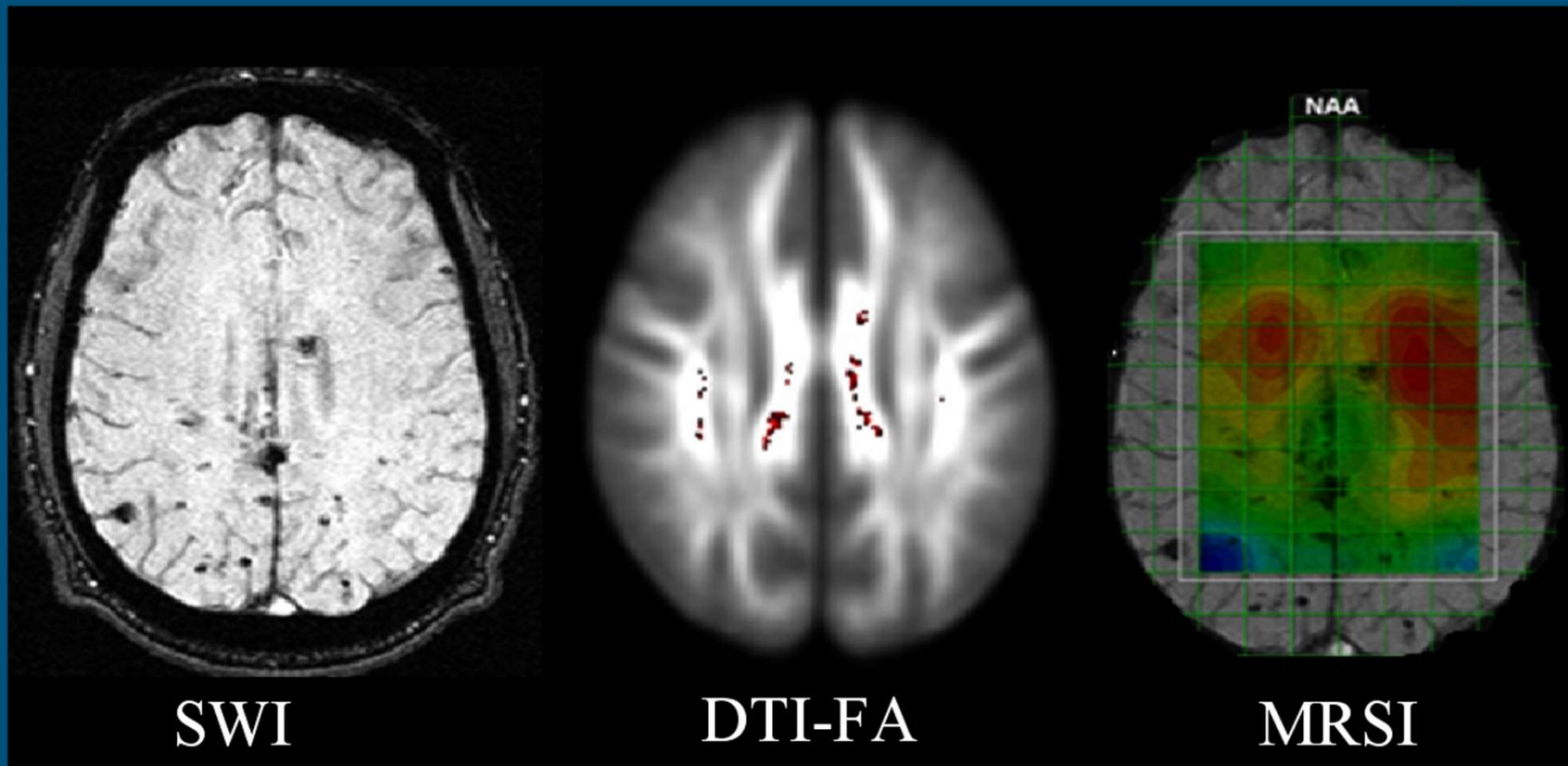
**Normal**



**Head Trauma**

Kraus MF. White matter integrity and cognition in chronic traumatic brain injury: a diffusion tensor imaging study. Brain. 2007 Oct;130 Epub 2007 Sept 14.

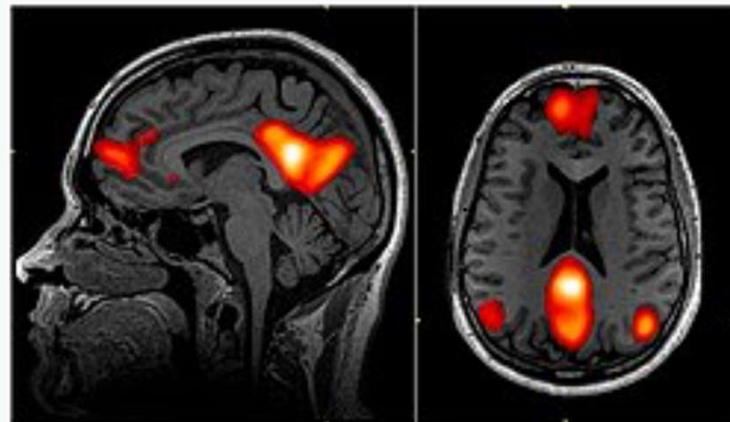
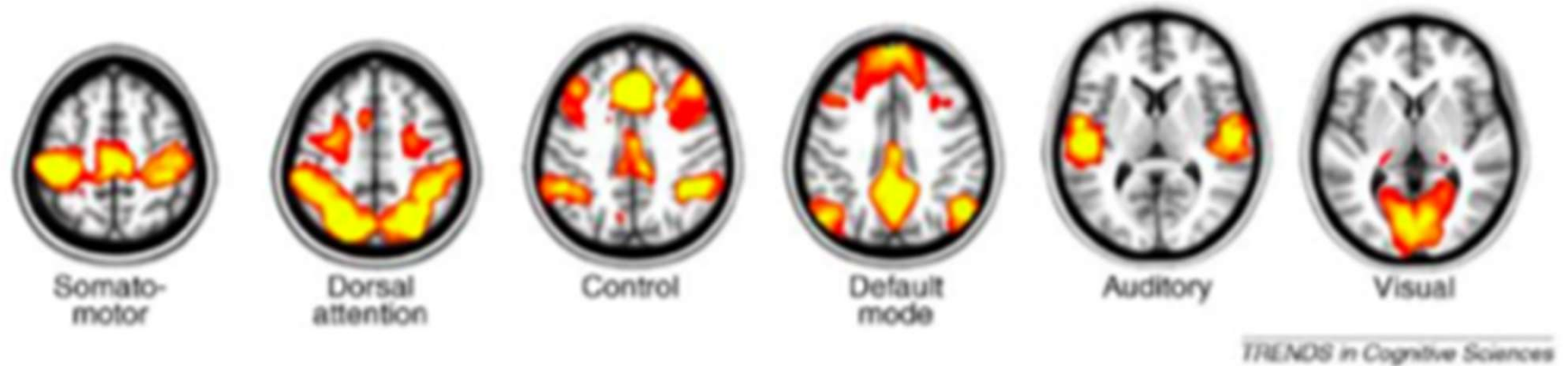




**Translational Neuroscience Program. Wayne State U. Zhifeng Kou, PhD.**



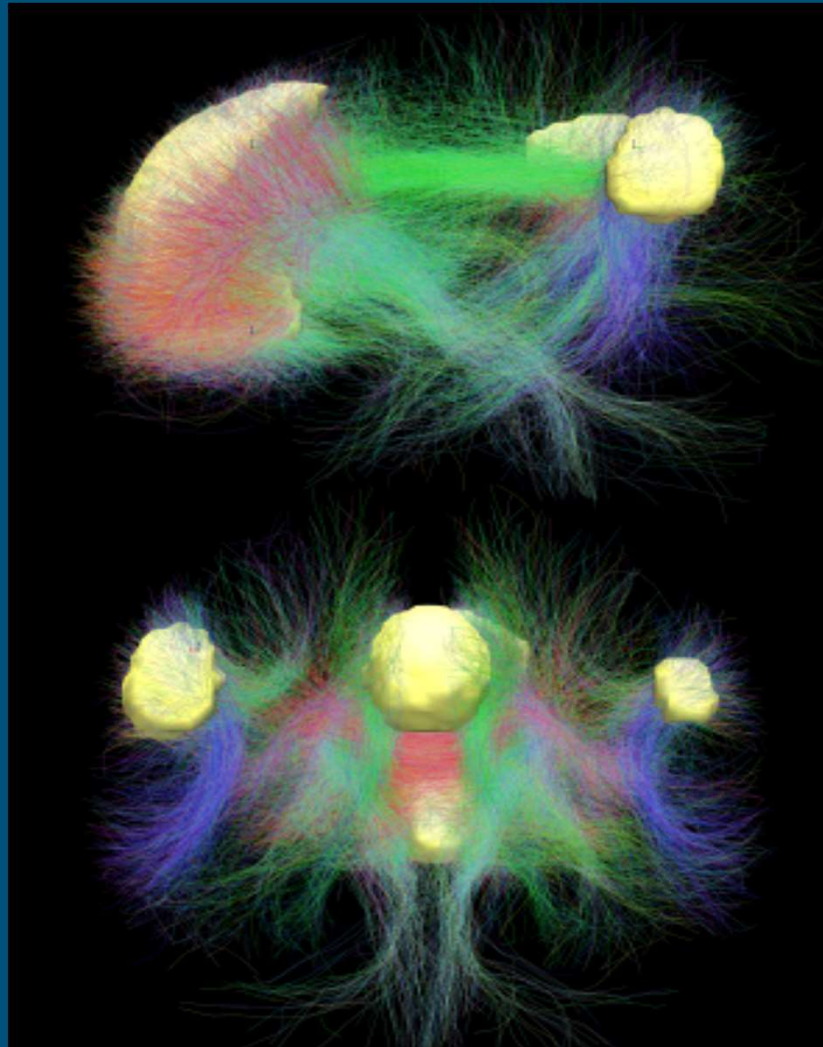
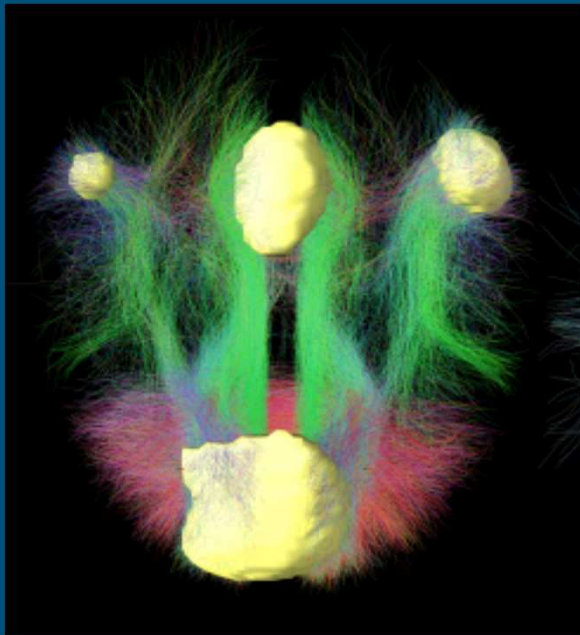
# Functional connectivity fMRI



Felix, et al. "The structural-functional connectome and the default mode network of the human brain." *NeuroImage*. 2013



# Default Mode Network (DMN) fMRI



Felix, et al. "The structural-functional connectome and the default mode network of the human brain." NeuroImage. 2013



# Resting-State Functional Connectivity Alterations Associated with Six-Month Outcomes in Mild Traumatic Brain Injury

Eva M. Palacios,<sup>1</sup> Esther L. Yuh,<sup>1,2</sup> Yi-Shin Chang,<sup>1</sup> John K. Yue,<sup>2,3</sup> David M. Schnyer,<sup>4</sup>  
David O. Okonkwo,<sup>5</sup> Alex B. Valadka,<sup>6</sup> Wayne A. Gordon,<sup>7</sup> Andrew I. R. Maas,<sup>8</sup> Mary Vassar,<sup>2,3</sup>  
Geoffrey T. Manley,<sup>2,3</sup> and Pratik Mukherjee<sup>1,2</sup>

*Journal of Neurotrauma, 2017*



# BOLD Functional (fMRI)

## Blood Oxygen Level Dependent fMRI



Show blood flows and metabolic usage using blood oxygen levels

- Assuming there is a direct relationship between neuronal activities and hemodynamics

**TBI Dilemma** – the nature of the injury fundamentally alter the relationship between neural activation and blood flow

- Research has shown that after TBI, cerebral perfusion is reduced (density of capillaries are reduced locally and diffusely); Metabolic failure after TBI can occur with normal perfusion;
- **Decoupling** (“mis-match”) between cerebral blood flow and metabolic rate of glucose

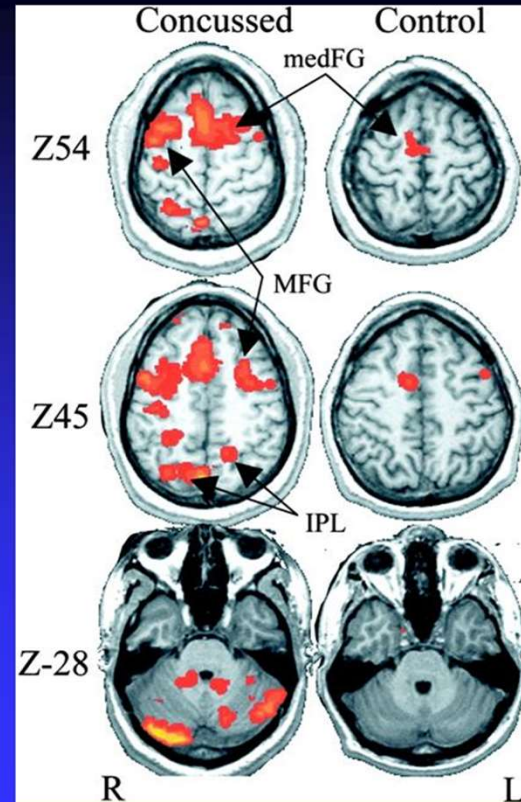
-J Medaglia. “Functional Neuroimaging in Traumatic Brain Injury: From Nodes to Networks”  
Frontiers in Neurology Aug 2017



# Functional MRI after Concussion



## fMRI and TBI



Prospective investigation of 8 collegiate football players had preseason fMRI scans obtained during a finger sequencing task

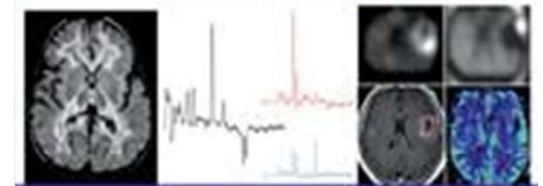
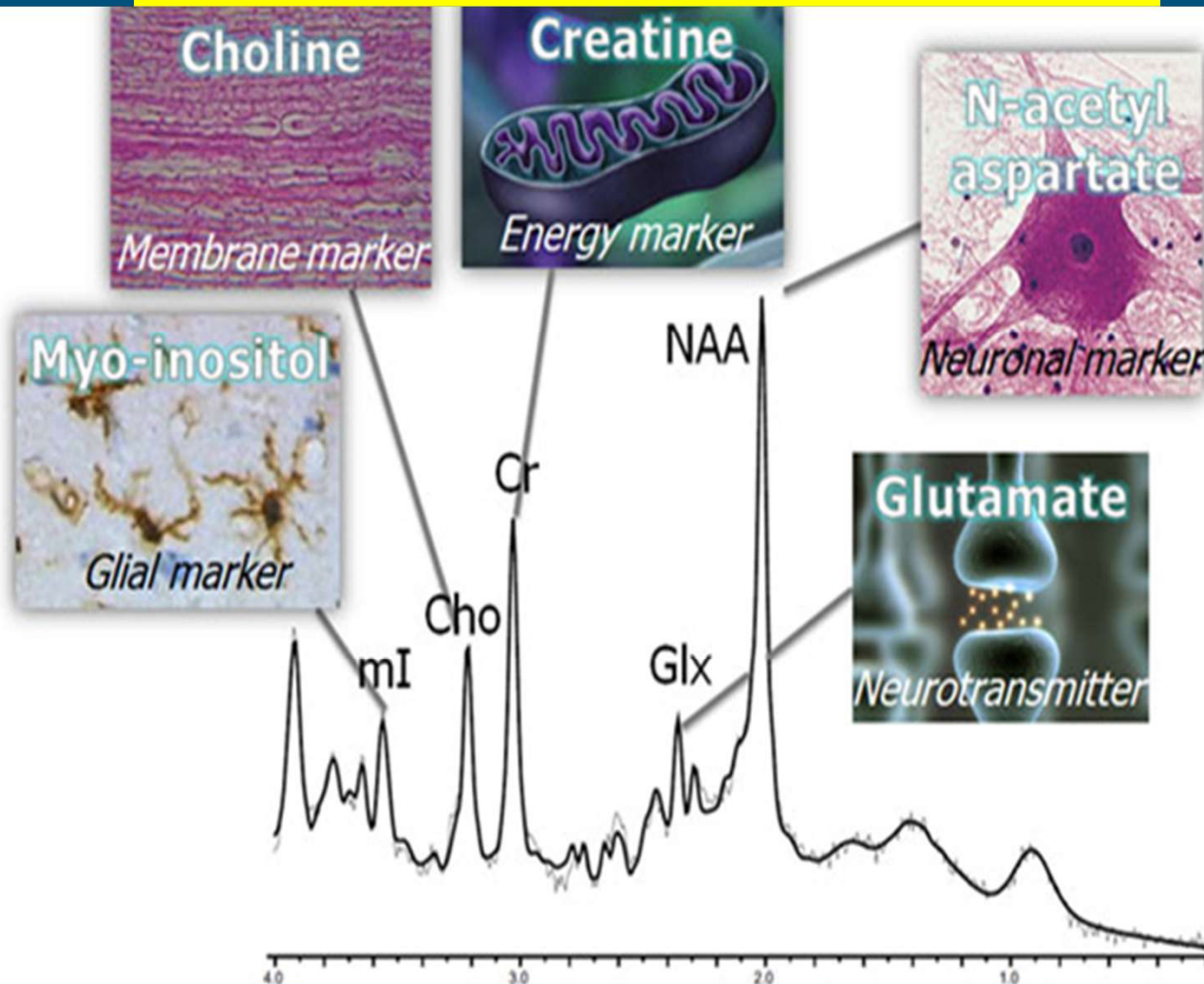
4 players experienced a concussion during the season and had a f/u fMRI within 1 week of the injury and the 4 controls had a f/u at the end of the season

Concussed players had marked increased activation in the areas of the parietal, lateral frontal and cerebellar regions

-fMRI and TBI Jantzen et al 2004



# MR Spectroscopy



## Clinical MR Spectroscopy

Techniques and Applications

Peter B. Barker  
Alberto Bizzi  
Nicola De Stefano  
Rao Gullapalli  
Doris D. M. Lin

CURRENT  
Medicine

Patterns of TBI: reduced NAA, Cr; increased Cho, Glutamate & MyoInoditol

-Emerging imaging tools for use with TBI research. J Neurotrauma Mar 2012



## BioMarkers in TBI



- Glial Fibrillary Acidic Protein (GFAP)
- Tau protein (cleaved tau, phosphorylated tau, total tau)
- Neurofilament Light Protein (NFL protein)
- Microtubular Associated Protein 2 (MAP2)
- Beta Amyloid protein
- ApoLipoprotein (ApoE)
- Myelin Basic Protein (MBP)
- Ubiquitin C-terminal Hydrolase L1 (UCH-L1)
- S100 B protein

Zetterberg et al. Nature Rev Neurol, 2013



# Concussion blood biomarkers?

The New York Times

*Concussions Can Be Detected With  
New Blood Test Approved by F.D.A.*

**NEWS**

**FORTUNE**  
**500**  
2017

**WebMD**



**CN** Health • Food • Fitness • Wellness • Parenting • Vital Signs Live TV  
**FDA approves first blood test for  
concussion**

Samples in a cold storage area at Banyan Biomarkers in San Diego. The company's blood test to detect concussions quickly after injuries was approved by the F.D.A. on Wednesday.  
Denis Poroy/Associated Press

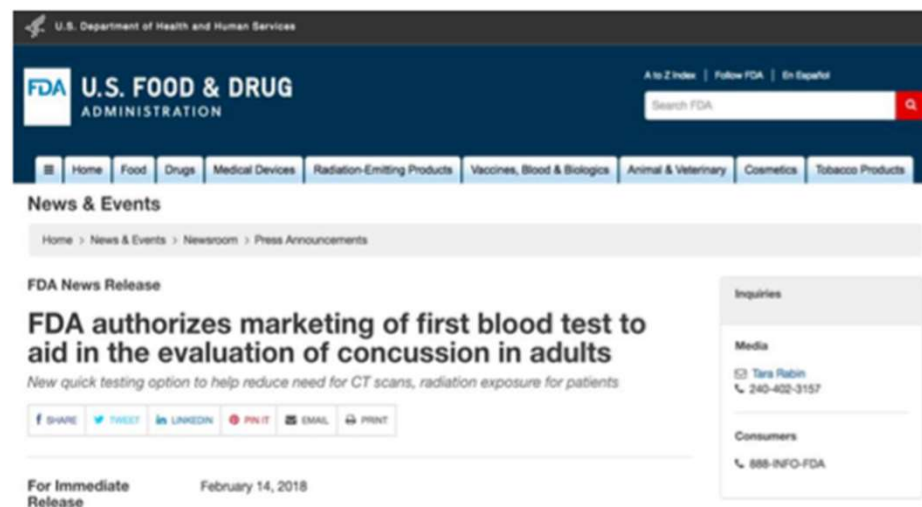
GFAB (+) predicts micro-bleed and help direct the need for CT Head

Christopher Giza. AAN Sports Concussion Conference 2018





**Concussion Blood Test Wins FDA Approval**  
New test could be useful in diagnosing brain injuries



- Multicenter study 1,947 individuals with mTBI
- Brain Trauma Indicator (UCH-L1/GFAP)  
Sensitivity: 97.5; Specificity: 99.6

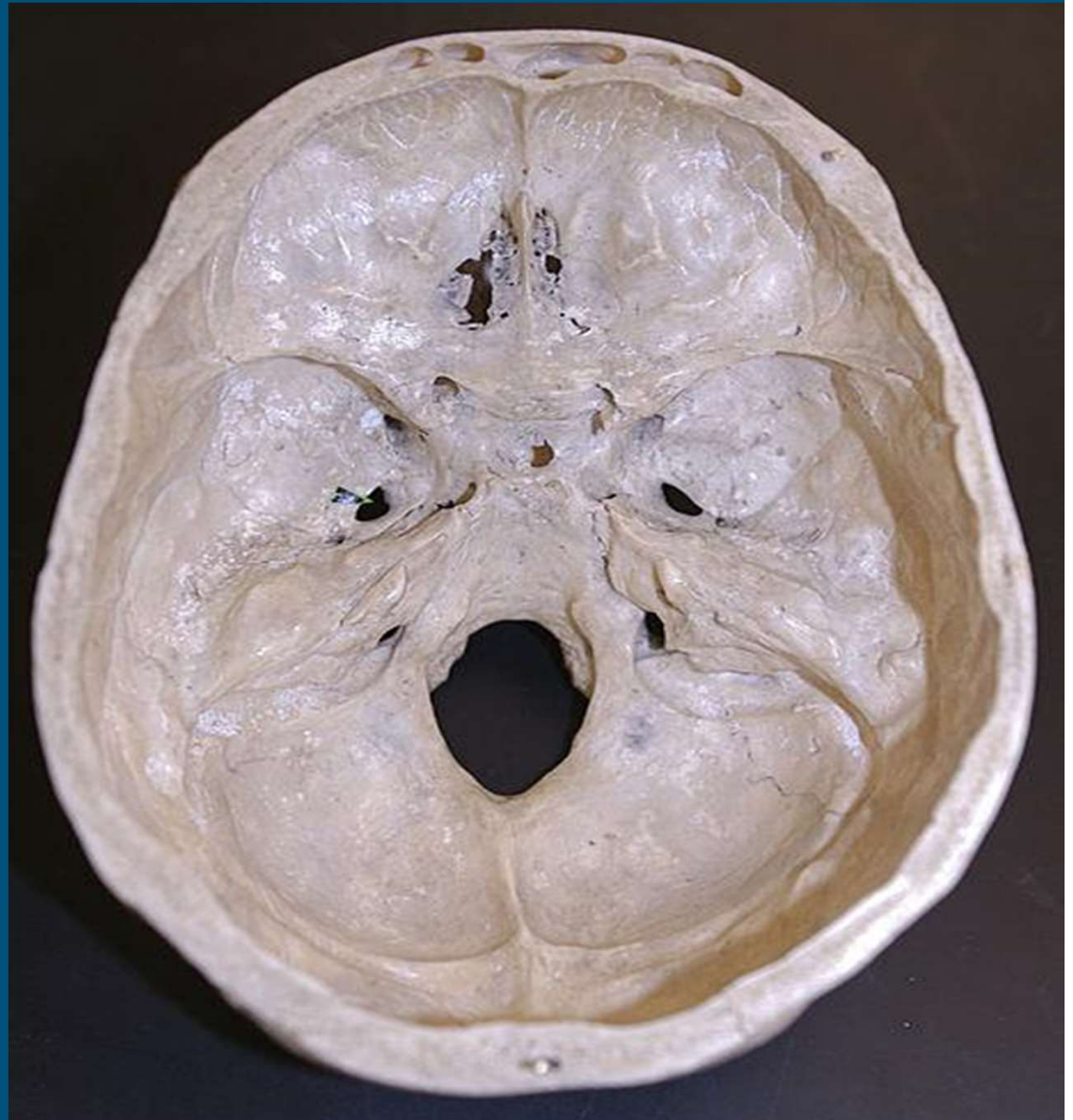
Christopher Giza. AAN Sports Concussion Conference 2018



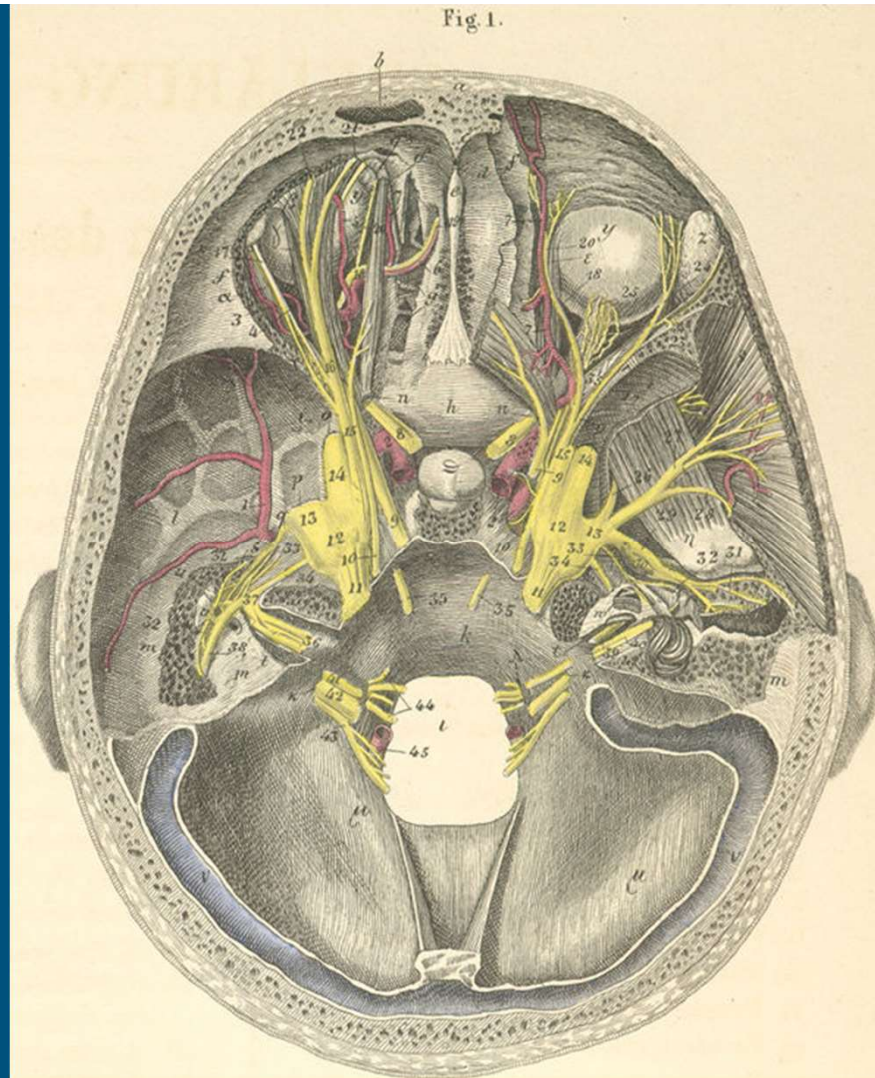


## “No Loss of Consciousness” in medical records

- **Amnesia** is extremely common because temporal lobes is often the most vulnerable in TBI
- The human brain is soft with consistency between butter and jelly.
- Medial temporal lobes: **Hippocampus** - responsible for memory formation, encoding and storage
- **Amygdala** – emotional processing







## Persistent Vertigo/Dizziness

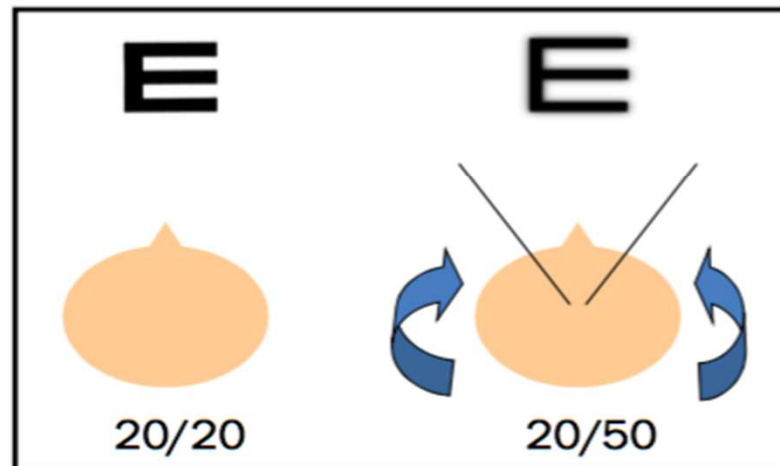
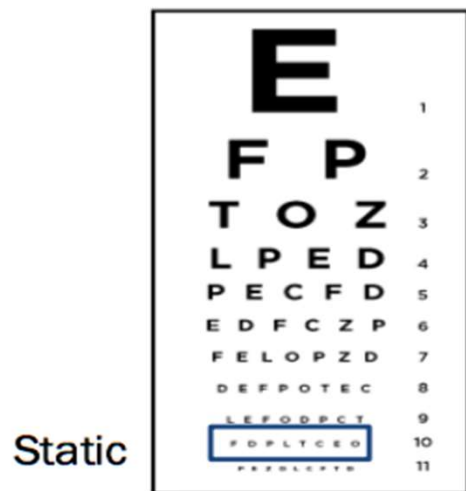
Vestibular/Auditory nerves (shear/stretch)

Vestibular-Ocular Network disturbances



# Gaze Stabilization

- Dynamic Visual Acuity Test (DVAT)



Gaze Stabilization requires integration of 1. Vestibular sensory organs, 2. Central Processing, 3. Motor output

**Symptoms:** Dizziness, Nausea, Blurry Vision, Difficulty working on computers, Reading, Dizziness in busy environments, Motion sensitivity

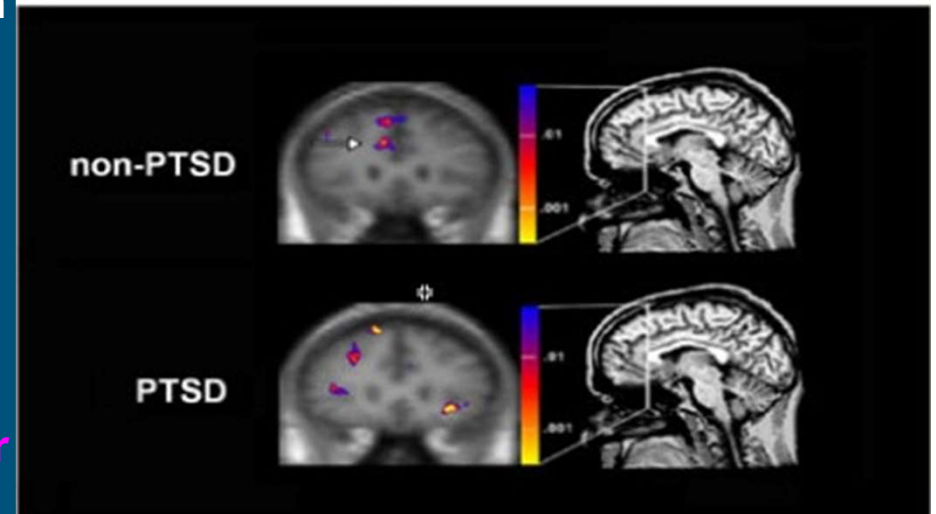


# Vulnerability and function of temporal lobes



- Disturbance of auditory processing and perception
- Impaired organization and categorization of verbal material
- Disturbance of visual input
- Disturbance of language perception
- Impaired short and long term memory
- Altered personality and affective disorder

## Reduced anterior cingulate function in PTSD (an fMRI study)



Shin et al., *Biological Psychiatry*, 50:932-942, 2001

## Alterations in amygdala response linked to PTSD

Functional MRI noted greater response in amygdala to fearful images in victims of trauma

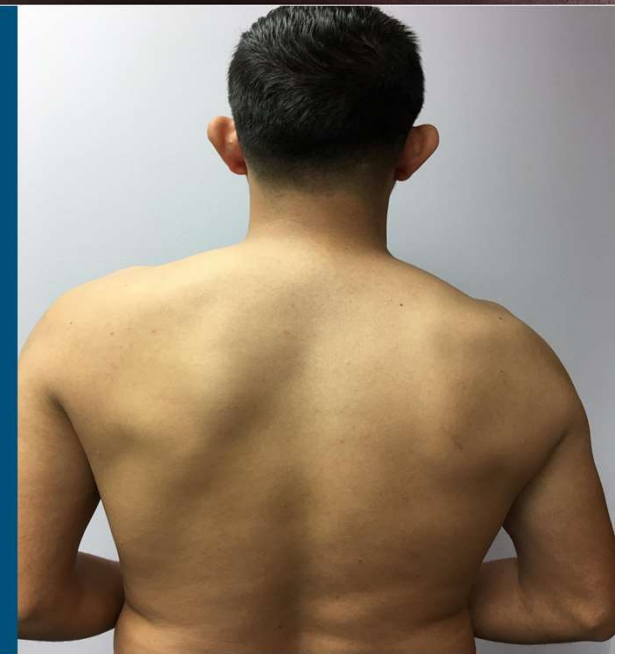
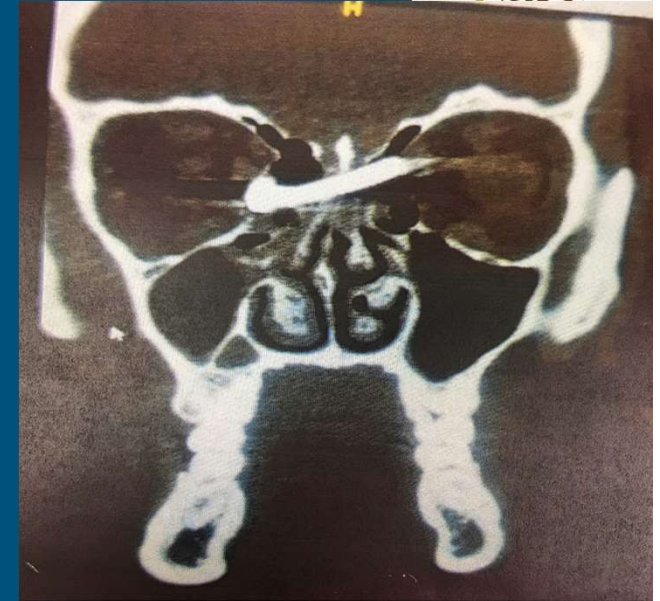
- Amygdala Reactivity and Anterior Cingulate Habituation Predict Posttraumatic Stress Disorder symptoms Maintenance After Acute Civilian Trauma. *Biological Psychiatry*, 2017



# What was Not in medical records...

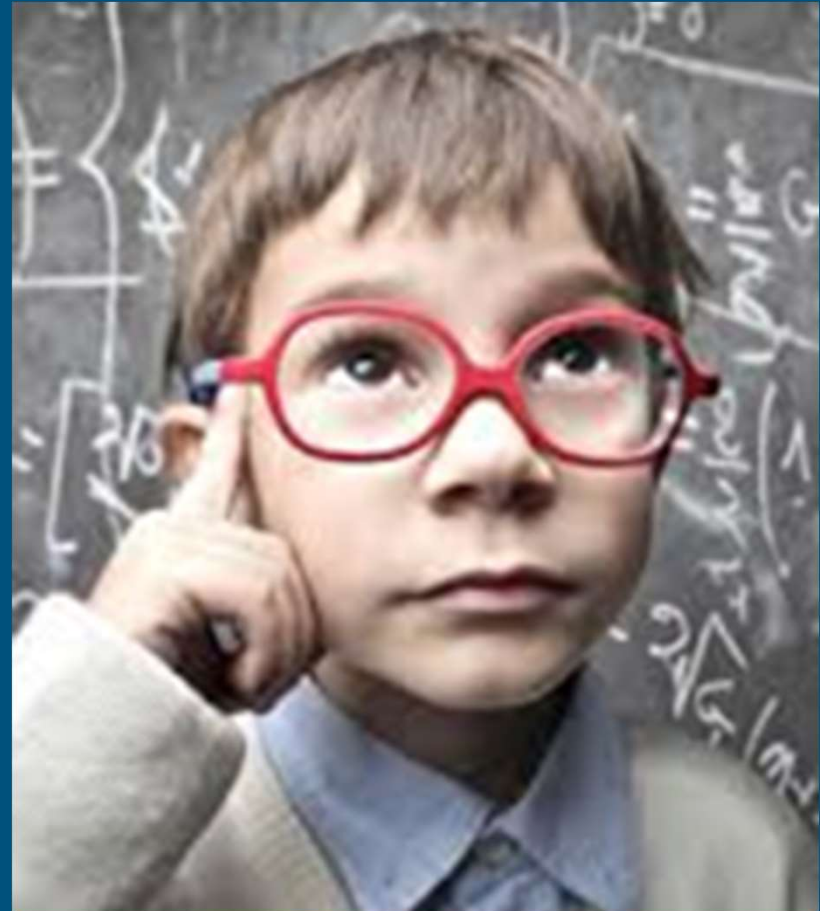
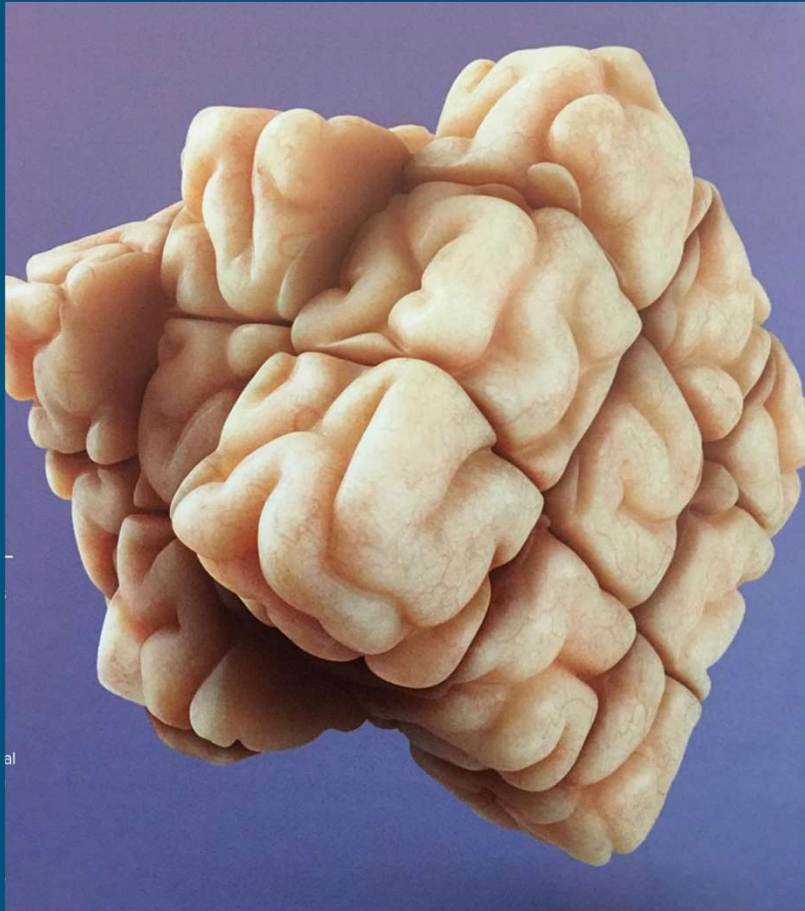


- Concussed persons' complaints are not always being documented, especially in records from the surgical fields (orthopedists, spine surgeons, plastic surgeons, etc.)
- “Face pain”
- Payers' restrictions (ethical issues?)
- Look for Review of System and nurses' intakes: neck and shoulder
- Beware of “**No LOC**” –Hallmark of concussion : confusion and amnesia





# Post-Concussive Syndrome





# Many symptoms of PCS are Non-specific to brain trauma



- *Physical* Symptoms (headache, dizziness, balance problem, noise sensitive, light sensitive, and/or fatigue)
- *Emotional* Symptoms (irritability, sadness, nervousness, and/or emotionally labile)
- Cognitive Symptoms (poor concentration, poor memory, and/or feeling mentally foggy)
- *Insomnia* (trouble falling asleep and/or sleeping less)

***Many people fit the diagnostic criteria for PCS despite having no history of concussion***



# Post-concussion Syndrome is Very Heterogeneous



- ICD-10
- DSM-IV/DSM-IV-TR (2000)
- “PCS” was removed from DSM-V (2013)



# Important contributory factors - highly individualized



- Mechanism of injury/trauma
- Underlying Physiologic factors : **cognitive reserve**, prior mood disorders, prior concussions, pre-existing headache disorders, concurrent medical problems.
- Psychosocial factors around the exposure : job satisfaction, perception of how the injury was handled, psychological trauma (robbery, witnessing death, etc.)
- Discovery of historical facts: prior concussion/claims



# ICD-10 Criteria for Postconcussion Syndrome



Must endorse persistent symptoms in at least 3/4 domains

- Physical/Somatic
- Emotional
- Cognitive
- Insomnia





# Take Away Message...



## Post-concussion syndrome is a Neuro-psychiatric Disorder

### Post-concussive syndrome (PCS) F07.8

- The ICD-10 criteria require the presence of **3 or more** of the following symptoms: **headache, dizziness, fatigue, irritability, insomnia, concentration or memory difficulty, and intolerance of stress, emotion or alcohol.**
- The DSM-V criteria require a history of TBI causing significant cerebral concussion, cognitive deficit such as inattention and/or memory problems; presence of at least **3 of 8** symptoms that persist for 3 months (for Chronic PCS): **fatigue, sleep disturbance, headache, dizziness, irritability, affective disturbance, personality change, apathy.**



# THREE NEUROLOGICAL AXIOMS



- Not every injury causes persistent neurological syndromes
- Not every clinical symptom occurred during the course of recovery is due to the concussion
- *Not every neurological syndrome after an exposure to mechanical force are directly related to the exposure*
- *i.e. After doesn't mean Because*



# Why do some people get worse over time?



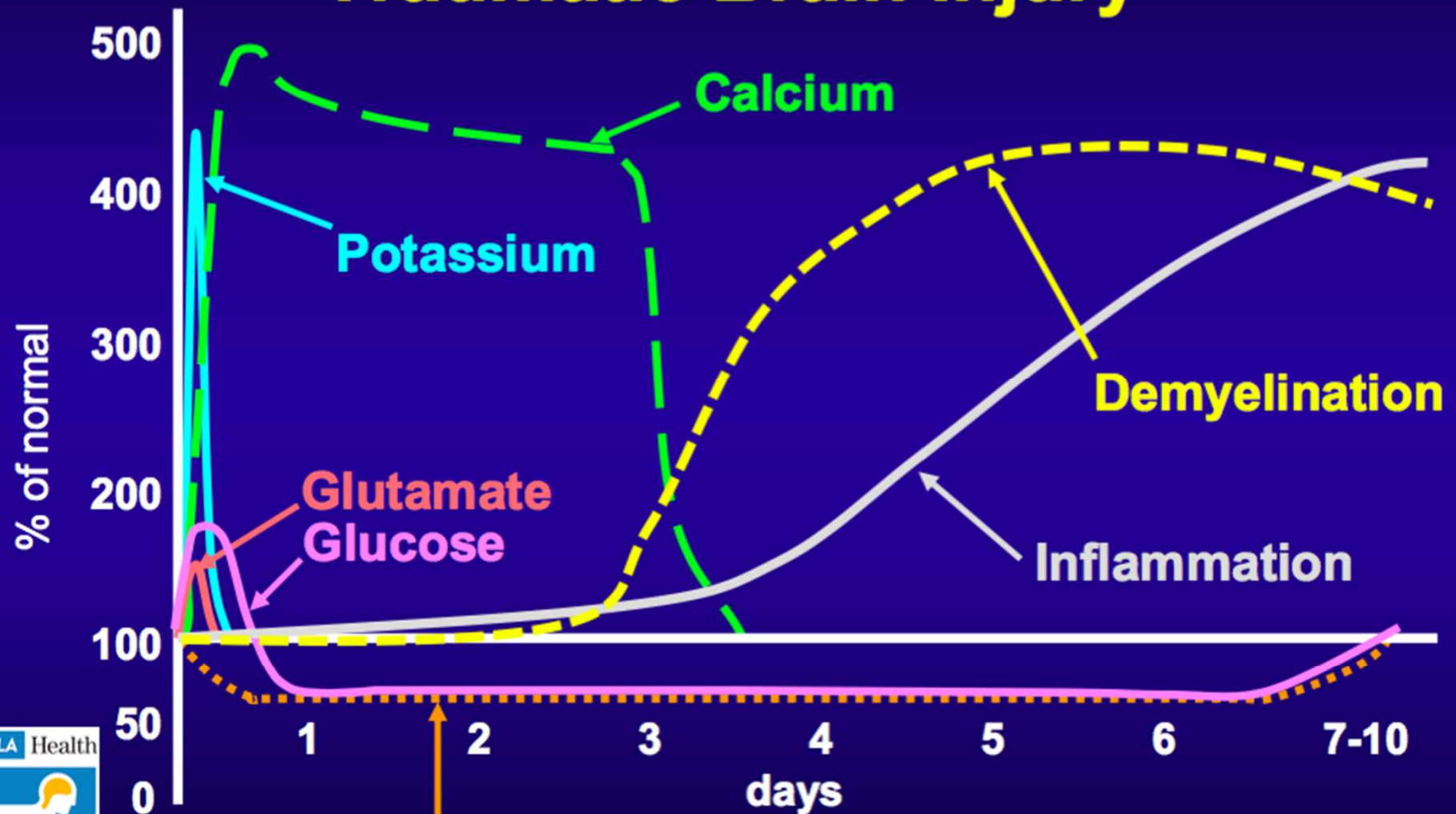
- Headache
- Fatigue
- Mood disorders
- Cognitive Issues
- Pain
- Chronic Traumatic Encephalopathy (CTE)

The chronic and evolving neurological consequences of traumatic brain injury. The Lancet Neurology. Oct 2017 Vol. 16: 813-825

Traumatic Brain Injury: A disease Process, Not an Event. J of Neurotrauma. August 2010:1358



# Neurometabolic Cascade Following Traumatic Brain Injury



UCLA Health



STEVE TISCH  
BrainSPORT  
PROGRAM

**Cerebral Blood Flow**

*Adapted from Giza & Hovda, Neurosurg 2014*



# Headaches is a very common prolonged condition



- **Post-traumatic Headache**

- The International Classification of Headache Disorders (ICHD-II) classifies Acute (APTH) and Chronic Post Traumatic Headache (CPTH) Attributed to Mild Head Injury. Both are based upon the standard definition of mild concussion (Criteria B below) and begin within 7 days of the injury. Chronic Post Traumatic Headache persists for more than 3 months.

## *5.2.2 Chronic post-traumatic headache attributed to mild head injury*

**A.** Headache, no typical characteristics known, and fulfilling criteria C and D

**B.** Head trauma with all the following:

1. Either no loss of consciousness, or loss of consciousness of <30 minutes' duration
2. Glasgow Coma Scale (GCS) > 13
3. Symptoms and/or signs diagnostic of concussion

**C.** Headache develops **within 7 days** after head trauma

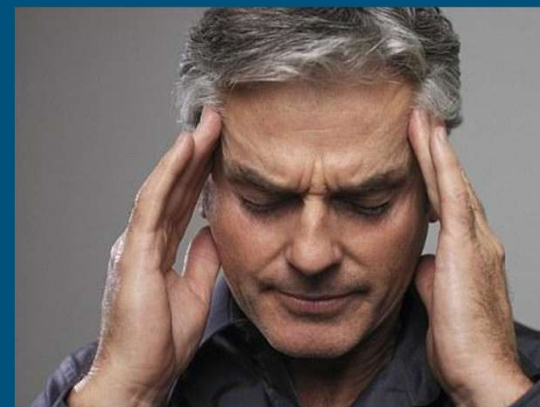
**D.** Headache persists for > 3 months after head trauma.



# Chronic Post-traumatic Headaches



- The percentage of patients with headache at 1 month varies from 31 to 90%, at 3 months from 47 to 78%, and at 1 year from 8 to 35%.  
-J of Neurotrauma 2011
- According to the latest AHA statistics, nearly **35%** of concussed patients have reported refractory headaches at **5** years.
- **Iatrogenic**: opioids for headaches
  - concurrent catastrophic orthopedic injuries
  - Delayed treatment/referral to neurologist
- **Medication Overuse Headaches** – pain increases over time (Central sensitization)







# Chronic Post-Traumatic Headaches

- Most of the Post-traumatic headaches have features of migraine (59%) or tension type (14%) headaches, which requires specific medications in addition to analgesics and NSAIDS

- J Neurotrauma 2011

→ Referral to neurologists/headache specialists (GPs tend to undertreat)

→ Additional challenge of reduced tolerance to medication side effects in concussed individuals: botulinum toxin injection/CGRP Antagonist when indicated

- Extra-cranial causes of headache triggers
  - Occipital/Trigeminal Neuralgia
  - Whip-lash neck injury; upper thoracic & shoulder pathology

-Seifert T. Posttraumatic Headache: a review. Curr Pain Headache 2010



# Prolonged conditions due to Ongoing Physiological disturbances : eg. Persistent Fatigue



## Neuroendocrine disturbances

### Hypothalamic-Pituitary-Adrenal (HPA) and/or Hypothalamic-Pituitary-Gonadal (HPG) dysfunction.

- Neuroendocrine abnormality is often a direct result of TBI and concussions.
- This problem is usually manifested as ***excessive fatigue, heat/cold intolerance and orthostatic dizziness, sexual dysfunction***
- Centrally secreted hormones include TSH, LH, FSH, Prolactin, DHEA, Cortisol, GnRH etc. are hormones that can be affected due to concussion and the imbalance will hinder one's recovery
- If uncorrected, the ongoing physiological dysfunction causes prolonged and worsening of symptoms overtime can often explain the chronic nature of symptoms

-Traumatic Brain Injury-Hormonal Dysfunction Syndrome “The Stealth Syndrome”. Mark Gordon, M.D. TBI-MedLegal.



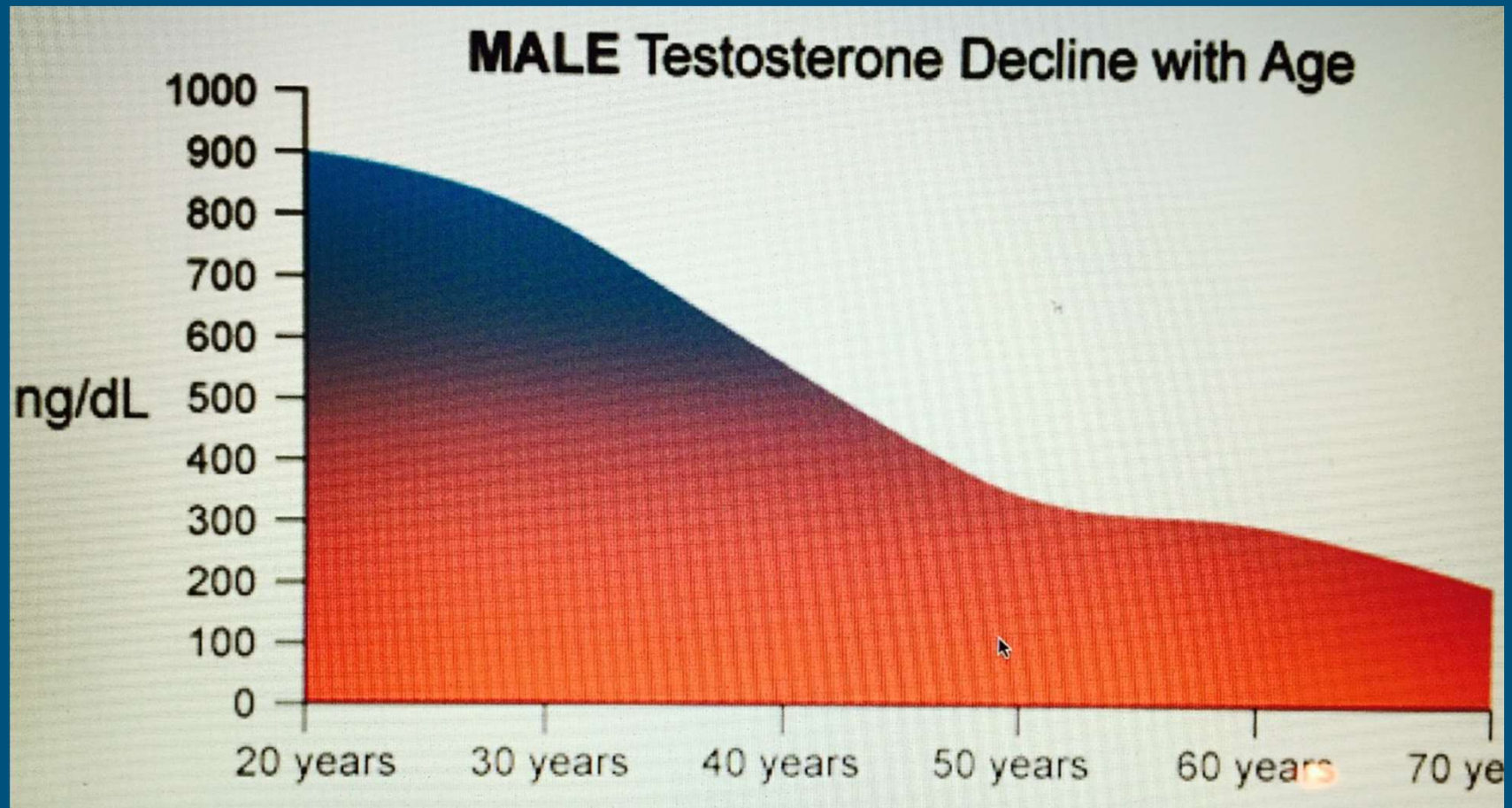
# Persistent Fatigue: Blood Work that are easy to obtain



- Centrally secreted hormones include TSH, LH, FSH, Prolactin, DHEA, Cortisol, GnRH etc. are hormones that can be affected due to concussion and the imbalance will hinder one's recovery.
- Thyroid function tests (TSH, T4, free T3)
- Total and Free Testosterone
- Adrenal function (DHEA, 4 point cortisol levels)



# Testosterone Age-based Normogram





Traumatic Brain Injury (TBI) causing hormonal dysfunction has been widely accepted by neuro-endocrine experts as a common, yet undertreated aspect of post-concussive syndrome. Therefore, there are potential means of improving one's psychological, physical, and physiological functioning. As of 2016, there are over 5,000 articles addressing the cause and effect of brain trauma on hormonal production.



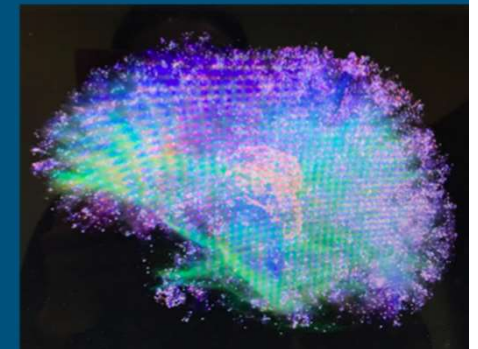
- **Patients with Severe Head Injury Should Have Hormone Assessment as Part of Routine Care according to the 86<sup>th</sup> Annual Meeting of the Endocrine Society.** June 21, 2004
- **The Clinical Significance of Major Depression Following Mild Traumatic Brain Injury** Psychosomatics 44:31-37, February 2003
- **Prevalence of hypopituitarism and growth hormone deficiency in adults long-term after severe traumatic brain injury.** Clin Endocrinol (Oxf) 2005 May;62(5):525-32
- **Hypopituitarism induced by traumatic brain injury in the transition phase.** Endocrinol Invest. 2005 Dec;28(11):984-989.
- **Prevalence of hypopituitarism and growth hormone deficiency in adults long-term after severe traumatic brain injury.** Clin Endocrinol (Oxf). 2005;62:525-532.
- **Neurobehavioral and quality of life changes associated with growth hormone insufficiency after complicated mild, moderate or severe traumatic brain injury.** J Neurotrauma. 2006;23:928-942.
- **Prevalence of Neuroendocrine Dysfunction in Patients Recovering from Traumatic Brain Injury** The J of Clinical Endocrinology & Metabolism, Vol. 86, 1 June 2001



# How do we help? Integrative therapy: highly individualized



- Address Sleep & Headaches
- Address Neuroendocrine issues
- Address Nutrition and Lifestyle factors
- sLORETA Brodmann area targeted Neurofeedback (NFB)
- Physical/Balance/Cognitive therapy
- Psychological counseling
- Work Transition







# Refractory/Challenging cases: Psychological Disorders – Co-Occurring or Aggravation

- Post Traumatic Stress Disorder (PTSD)
- Mood Disorders : Anxiety and Depression
- There is an increasing awareness of the relationship between PTSD and brain injury in both civilian and military populations.
- Studies suggests that, as with depression, PTSD can amplify post concussive *symptoms* after a TBI and complicate recovery.



# Psychological Reactions to Brain Injury (any bodily injury)

These ***Psychological***  
Reactions:

- Depression
- Anger
- Frustration
- Reduced Vigor
- Anxiety and Worry (\$)
- Reduced Self-Esteem
- Fear of Re-Injury

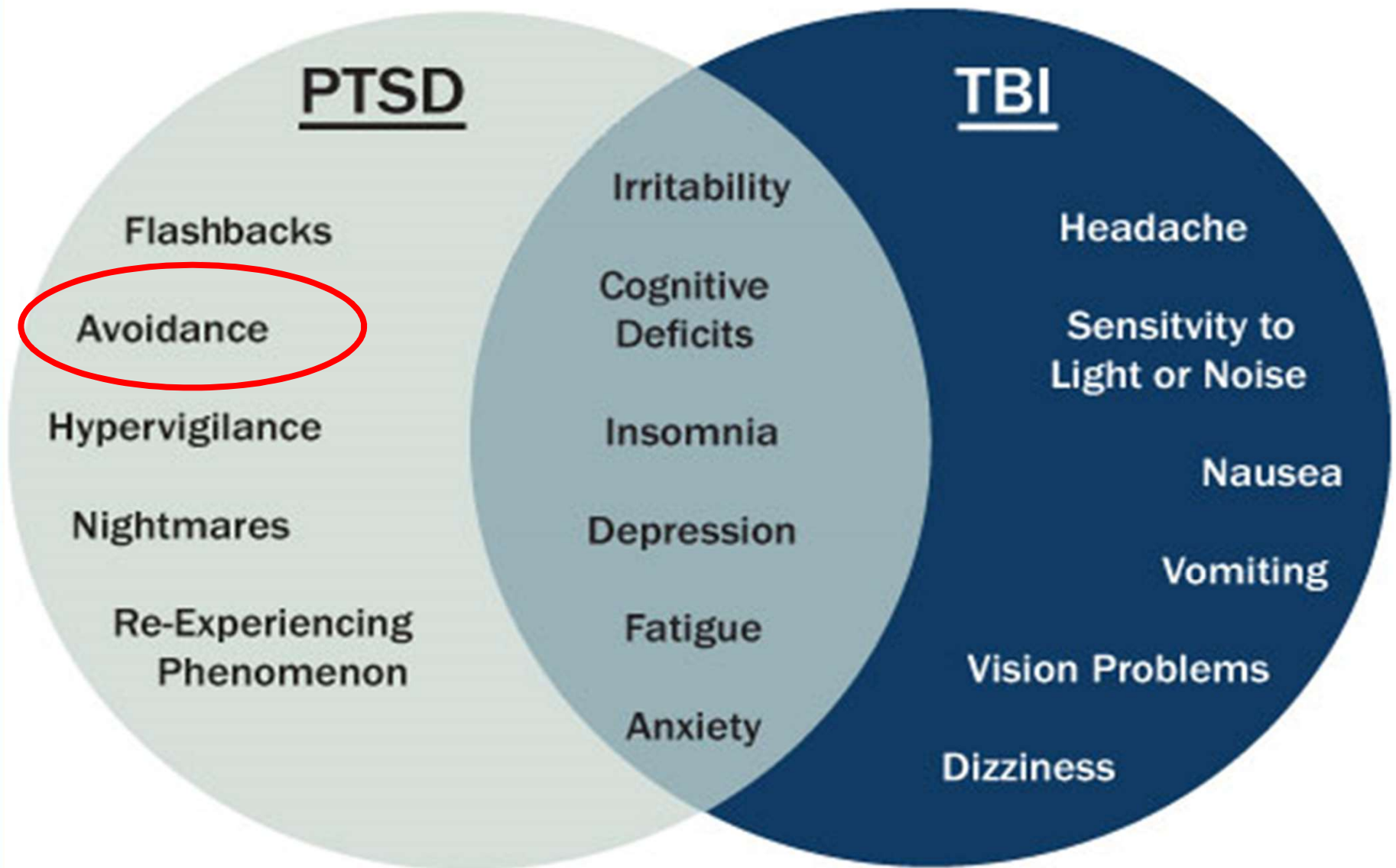
Can Contribute to These  
***Physical*** Symptoms:

- Sleep Problems
- Fatigue
- Headaches

And thus **Mimic** or  
**Amplify Post-TBI**  
**Symptoms**



# Overlap Symptoms

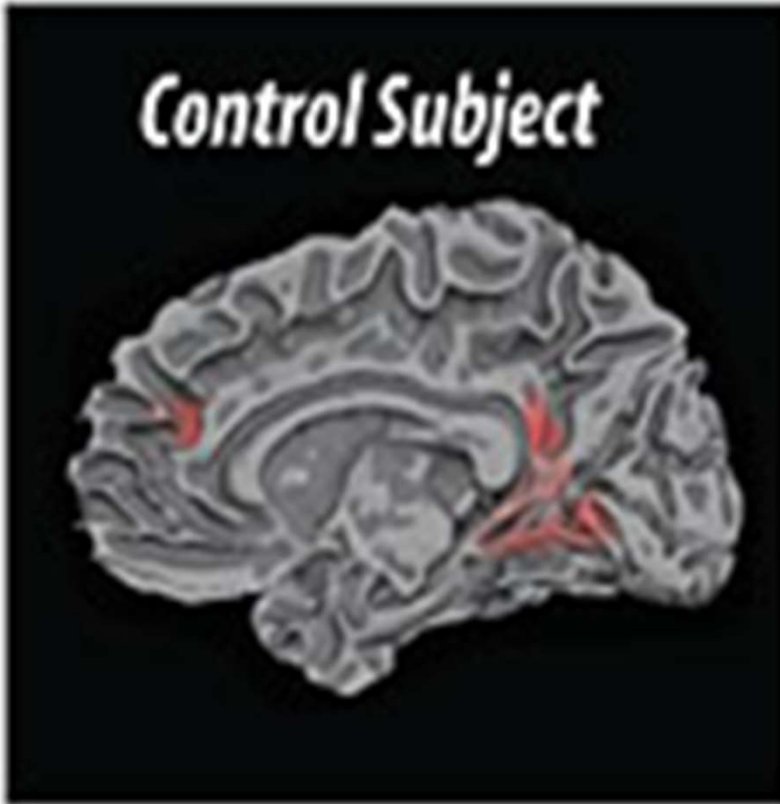




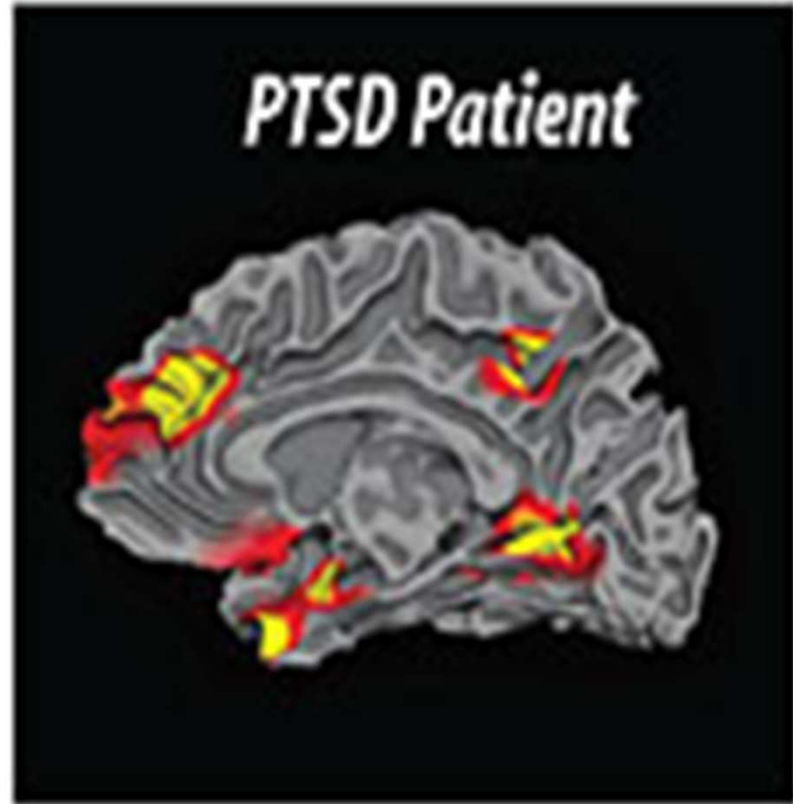
# Posttraumatic Stress Disorder PTSD



***Control Subject***



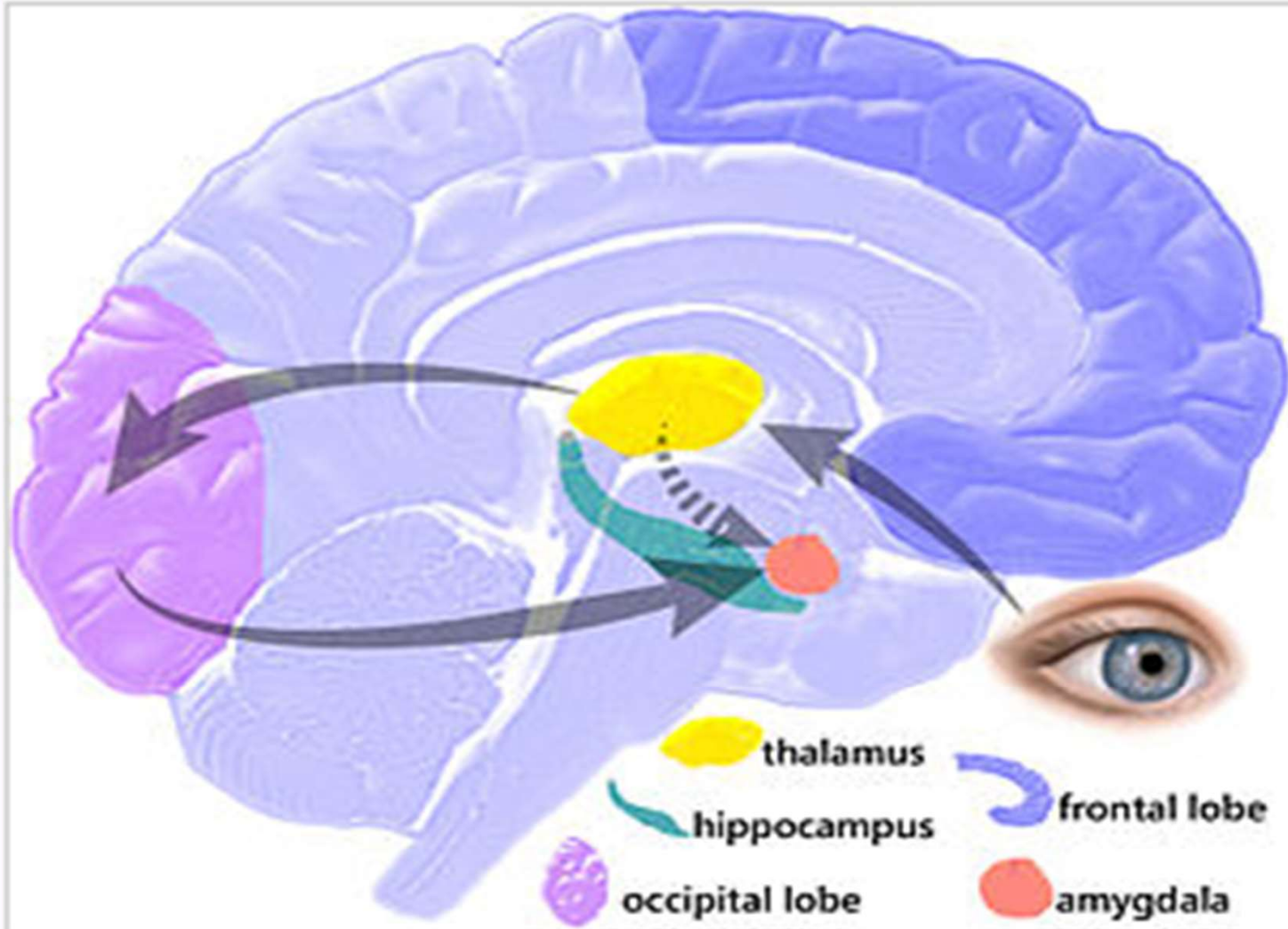
***PTSD Patient***



*A magnetoencephalograph of the resting-state brain shows hyperaroused amygdala in a PTSD patient.*



# Amygdala Hijack in PTSD



Amygdala hijack - fear caused by optical stimulus.





# Neuropsychological Testing



1. General intelligence
2. Attention and concentration abilities
3. Learning and memory function
4. Language function
5. Visual-spatial abilities
6. Auditory function
7. Executive functions
8. Personality and emotional functions





# Neuropsychological Testing

- Uncover psychological factors like Depression, Anxiety, Panic disorders, PTSD, Somatoform Disorders (psychosomatic pain, partial or complete malingering)
- Pre/Post accident general intelligence
- Pre/Post accident Social factors
- Cognitive functioning
- Validity measures should be incorporated in legal cases



# Validity Measures in Neuropsychological Testing



## Paulhaus Deceptive Scale (PDS)

- Impression Management (IM) & Self-Deceptive Enhancement (SDE) Scale – 40-item instrument to identify conscious distortion of their responses

## Structured Interview of Malingered Symptoms (SIMS)

VRIN-r and VRIN-r – suggestive of level of cooperation and consistency

## Infrequent Somatic Responses

## Fake Bad Symptom

## Response Bias Scale





# Neuropsychological Testing

**Cannot** determine the cause of the problem

- Neuro-psychological testing alone Does Not diagnose Post Concussive Syndrome
- **Concussion** and **Post-Concussive Syndrome** are **clinical** diagnoses, which requires compilation of **all** contributory physiological, psychological and social factors, situation/mechanism of trauma, neurological examination and available neurodiagnostics





What does it take for the brain to  
recover?

How long does it take for the brain to  
recover?

What factors hinder brain recovery?

Does clinical recovery correlate with brain  
recovery?

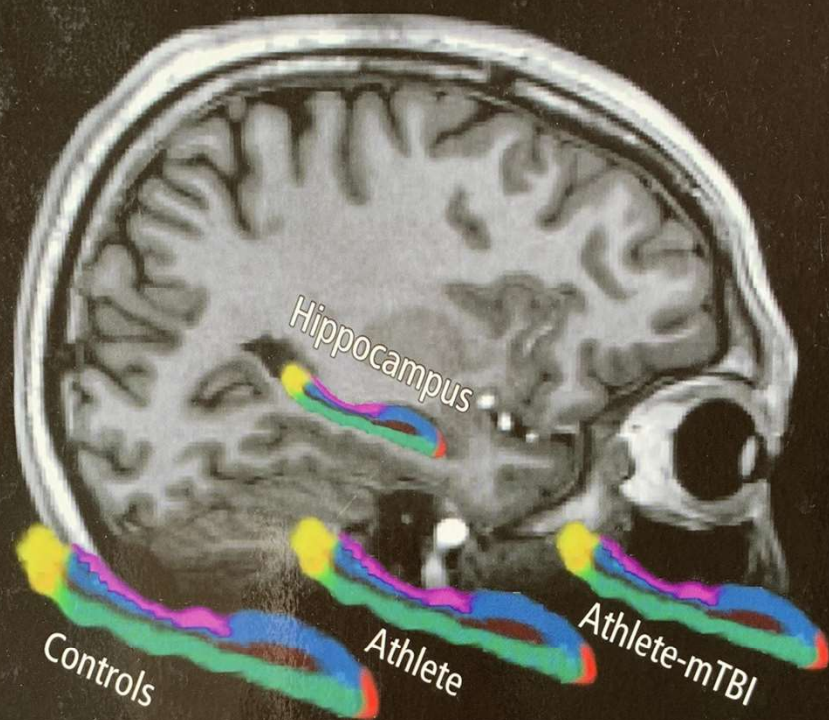
**NCAA-DOD Grand Alliance CARE Consortium**



# Paradigm Shift:

1. “1. Concussion is a mechanical event. It may or may not produce a brain injury. The word does not mean an amount of injury, a duration of effect, or a group of symptoms.’
2. Concussive Brain Injury (CBI) is neither physically nor symptomatically homogenous. It is heretrogenous, not only due to variation in brain changes in the moments after impact, but also due to the interactions between thousands of physiological changes and a lifetime of bio-psycholoical individuality.
3. It is misleading to characterize CBI as a focal traumatic event comparable to a broken arm. It is a dazzlingly complex, remarkably diverse, and often longlived cerebral process. It is something special, for trauma to brains alone perturbs the tissue of identity.”





# Concussion and Traumatic Encephalopathy

Causes, Diagnosis and Management

EDITED BY Jeff Victoroff  
and Erin D. Bigler

CAMBRIDGE

Medicine

Fourth Edition

# TRAUMATIC BRAIN INJURY

REHABILITATION, TREATMENT,  
AND CASE MANAGEMENT



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EDITED BY  
MARK J. ASHLEY  
DAVID A. HOVDA

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CRC Press  
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# Long term effects:

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- Traumatic Brain Injury: A disease Process, Not an Event. J of Neurotrauma. August 2010:1358
- The chronic and evolving neurological consequences of traumatic brain injury. Lancet Neurology. Oct 2017 Vol. 16: 813-825
- Association of Mild Traumatic Brain Injury With and Without Loss of Consciousness With Dementia in US Military Veterans. JAMA Neurology. May 7, 2018
- Association between Traumatic Brain Injury and Late Life Neurodegenerative Conditions and Neuropathological Findings. JAMA Neurol. 2016 September 01; 73(9): 1062–1069
- Alzheimer's Association 2019 Official statements: Traumatic Brain Injury